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U.S. Department
of Energy

COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY D

NIAGARA FALLS STORAGE SITE

LEWISTON, NEW YORK

A. J. BOERNER

Radiological Site Assessment Program
Manpower Education, Research, and Training Division

FINAL REPORT

March 1984

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LEWISTON, NEW YORK

Prepared for

U.S. Department of Energy
as part of the
Formerly Utilized Sites -- Remedial Action Program

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INTRODUCTION

Beginning in 1944, the Manhattan Engineer District and its successor, the Atomic Energy Commission (AEC), used portions of the Lake Ontario Ordnance Works (now known as the Niagara Falls Storage Site (NFSS) and associated off-site properties) approximately 3 km northeast of Lewiston, New York, for storage of radioactive wastes. These wastes were primarily residues from uranium processing operations; however, they also included: contaminated rubble and scrap from decommissioning activities, biological and miscellaneous wastes from the University of Rochester, and low-level fission-product waste from contaminated-liquid evaporators at the Knolls Atomic Power Laboratory (KAPL). Receipt of radioactive waste was discontinued in 1954, and following cleanup activities by Hooker Chemical Co., 525 hectares of the original 612-hectare site were declared surplus. This property was eventually sold by the General Services Administration to various private, commercial, and governmental agencies.[1]

SCA Chemical Services, Inc. is the current owner of a tract identified as off-site property D (see Figure 1). A radiological survey of that tract, conducted in May through August 1983, is the subject of this report.

SITE DESCRIPTION

Figure 2 is a plot plan of off-site property D. The property is rectangular in shape and measures approximately 812 m long by 280 m wide. It occupies a total area of 23 hectares. The site is bounded on three sides by roads: "H" Street on the north, MacArthur Street on the east, and "5" Street on the west. Chain link fences cross the property in a north-south direction near the extreme eastern and western edges. The western portion of this property is largely occupied by landfill areas which are accessed by unpaved roads. The property contains two major drainage ditches (the ditch near the western boundary has been only recently constructed). There are also four waste treatment or retention ponds on the site. There is one small, badly deteriorated, wooden structure; originally this building was part of the munitions operations which occupied the site prior to use by MED/AEC. With the exception of the landfill and several treatment pond berms, the land is relatively level. Most of the land has been cleared although small areas of trees and brush remain along the northern perimeter.

Radiological History

There is no evidence of contaminated material burials on property D; however, the 1971-72 AEC survey identified two small areas of possible surface contamination.[1,2] One of these was located near the northwest corner of the property, about 60 m south of "H" Street and 80 m west of Castle Garden Road. Direct radiation levels in this area ranged up to 40 μR/h following the 1972 cleanup operation. The second elevated area was in the mid-eastern section of the property, near the south end of First Street. This area, which had direct radiation levels up to 25 μR/h, is presently covered by a chemical landfill. A 1980 mobile scan by the Oak Ridge National Laboratory indicated above-background levels along "H" Street and minor spots along the north-south roads.[3] It is possible that some of these previously identified areas may have been disturbed or relocated as a result of on-going construction and property maintenance activities conducted by SCA.

SURVEY PROCEDURES

The comprehensive survey of NFSS off-site property D was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during May-August 1983. The survey was in accordance with a plan dated February 3, 1983, approved by the Department of Energy. The objectives and procedures from that plan are presented in this section.

Objective

The objective of the survey was to provide a comprehensive assessment of the radiological conditions and associated potential health effects, if any, on property D. Radiological information collected included:

1. direct radiation exposure rates and surface beta-gamma dose rates,
2. locations of elevated surface residues,
3. concentrations of radionuclides in surface and subsurface soil,
4. concentrations of radionuclides in surface and ground water, and
5. concentrations of radionuclides in sediment samples from drainage ditches.

Procedures

1. Brush and weeds were cleared as needed to provide access for gridding and surveying and a 40 m grid system was established by McIntosh and McIntosh of Lockport, NY, under subcontract. The grid system is shown on Figure 3.

2. Walkover surface scans were conducted over all accessible areas of the property. Traverses were at 2-5 m intervals on those areas that were relatively inaccessible and had no history of radioactive use. Scanning intervals were 1-2 m along all roads, in areas previously identified as having elevated radiation levels, and in other areas where direct radiation measurements suggested possible contaminated residues. Portable gamma NaI(Tl) scintillation survey meters were used for the scans. Locations of elevated contact radiation levels were noted and surface exposure rates were measured at these locations.

3. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at 40 m grid intervals. Measurements were performed using portable gamma NaI(Tl) scintillation survey meters. Conversion of these measurements to exposure rates in

microroentgens per hour ($\mu R/h$) was in accordance with cross calibration with a pressurized ionization chamber.

4. Beta-gamma dose rate measurements were performed 1 cm above the surface at 40 m grid intervals. These measurements were conducted using thin-window (<7 mg/cm^2) G-M detectors and portable scaler/ratemeters. Measurements were also obtained with the detector shielded to evaluate contributions of nonpenetrating beta and low-energy gamma radiations. Meter readings were converted to dose rates in microrads per hour ($\mu rad/h$) based on cross calibration with a thin-window ionization chamber.

5. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at each accessible 40 m grid interval.

6. At selected locations of elevated surface radiation levels beta-gamma dose rates and exposure rates at 1 m above the surface were also measured. Surface soil samples were obtained from these locations and, following sampling, the surface exposure levels were remeasured for comparison with presampling levels.

7. Detection Sciences Group of Carlisle, MA, performed ground penetrating radar surveys at proposed borehole locations to assure that subsurface piping and utilities were not damaged during drilling. In some cases, slight relocations of borehole locations were required.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Twelve boreholes were drilled by Site Engineers, Inc., of Cherry Hill, NJ, and Earth Dimensions of Aurora, NY, using truck mounted 20 cm diameter hollow-stem augers. The locations of these boreholes are shown on Figure 4.

Gamma radiation scans were performed in the boreholes to identify the locations of elevated direct radiation levels which might indicate subsurface residues. Radiation profiles in the boreholes were determined by measuring gamma radiation at 15–30 cm intervals between the surface and ground water or the hole bottom. A collimated gamma scintillation detector and portable scaler were used for these measurements.

Ground water samples of approximately 3.5 liters were collected from five borehole locations. The samples were collected using a hand bailer. Soil samples of approximately 1 kg each were collected from various depths in the holes by scraping the sides of each borehole with an ORAU designed sampling tool.

9. Four water samples were collected from areas of standing (surface) water (see Figure 5).

10. Three sediment samples were collected from ditches located near the periphery and center of the property (refer to Figure 5).

11. Twenty soil samples and seven water samples were collected from the Lewiston area (but not on NFSS or associated off-site properties) to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were measured at locations where baseline soil samples were collected. The locations of the baseline samples and background measurements are shown on Figure 6.

Sample Analyses and Interpretation of Results

Soil samples were analyzed by gamma spectrometry. Radium-226 was the major radionuclide of concern, although spectra were reviewed for U-235, U-238, Th-232, Cs-137, and other gamma emitters. Water samples were analyzed for gross alpha and gross beta concentrations.

Additional information concerning analytical equipment and procedures is in Appendix A.

Results of this survey were compared to the applicable guidelines for formerly utilized radioactive materials handling sites, which are presented in Appendix B.

RESULTS

Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil, determined for 20 locations (Figure 6) in the vicinity of the NFSS, are presented in Table 1-A. Exposure rates ranged from 6.8 to 8.8 μR/h (typical levels for this area of New York). Concentrations of radionuclides in soil were: Ra-226, <0.09 to 1.22 pCi/g (picocuries per gram); U-235, <0.14 to 0.46 pCi/g; U-238, <2.20 to 6.26 pCi/g; Th-232, 0.32 to 1.18 pCi/g; and Cs-137, <0.02 to 1.05 pCi/g. These concentrations are typical of the radionuclide levels normally encountered in surface soils.

Radioactivity levels in baseline water samples are presented in Table 1-B. The gross alpha and gross beta concentrations ranged from 0.55 to 1.87 pCi/l (picocuries per liter) and <0.63 to 14.3 pCi/l, respectively. These are typical of concentrations normally occurring in surface water.

Direct Radiation Levels

Direct radiation levels, measured at 40 m grid intervals, are presented in Table 2. The gamma exposure rates at 1 m above the surface at these grid points ranged from 6 to 10 μR/h (average 7 μR/h). Surface contact gamma exposure rates and beta-gamma dose rates were 5 to 10 μR/h (average 7 μR/h) and 5 to 35 μrad/h (average 17 μrad/h), respectively. At most locations, measurements performed with the detector shielded averaged approximately 20% less than those with the unshielded detector. This indicates only a small portion of the surface dose rate is due to nonpenetrating beta or low-energy photon radiations.

The walkover survey identified numerous isolated spots of elevated contact radiation levels. These locations are indicated on Figure 7 and associated radiation levels are presented in Table 3. Surface contact gamma exposure rates ranged from 29-3000 μR/h; the maximum was measured at grid point 384N, 312E. Exposure rates at 1 m above the surface ranged from 8 to 110 μR/h. Beta-gamma dose rates ranged from 29-6450 μrad/h. The maximum dose rate was recorded at grid coordinate 376N, 292E. Contact exposure and beta-gamma dose rates were reduced by soil sampling at many of these locations; this indicates that most of the contamination is in small, discrete pieces of material rather than diffused throughout the soil.

Radionuclide Concentrations in Surface Soil

Table 4 lists the concentrations of radionuclides measured in surface soil from 40 m grid intervals. These samples contained Ra-226 concentrations ranging from <0.16 to 2.44 pCi/g. The highest level was in the sample collected at grid point 538N, 760E. A few additional samples contained Ra-226 concentrations exceeding those in the baseline soil, but none exceeded 5 pCi/g above the baseline level. Several of these samples also contained slightly elevated U-238 concentrations. The highest U-238 concentration was 8.40 pCi/g at grid coordinate 400N, 740E. Concentrations of U-235, Th-232, and Cs-137 were not significantly different from those in baseline samples. No other gamma emitting radionuclides were noted in these samples.

Radionuclide concentrations in samples from locations of elevated contact radiation levels are presented in Table 5. Concentrations of Ra-226 in these samples ranged from 0.95 to 11,200 pCi/g; the maximum concentration was measured in a piece of rock-type material (sample B8) from grid point 460N, 742E. Most of the other samples which contained high Ra-226 levels were also pieces of this same material and ranged in size from approximately 200 g to 1.5 kg. These samples also contained elevated

U-238 and Th-232 levels. The rock sample, B1B, from location 539N, 222E, contained 403 pCi/g of U-238 and 553 pCi/g of Th-232 - the highest levels of these two radionuclides measured in samples from property D.

Sample B12 consisted of several chips from a large metallic-looking mass weighing an estimated 30-40 kg. Samples B10 and B11 contained small objects which were the source of the contamination. Sample B10 contained a small white chip (probably lead cake) having a total activity of 0.31 μCi of Ra-226; sample B11 was a ceramic device known as a "spark gap" and contained 25.4 μCi of Cs-137.

Borehole Gamma-Logging Measurements

The results of gamma scintillation measurements in boreholes indicate no subsurface contamination. The gamma count rates determined by the borehole measurements were reliable indicators of elevated subsurface radionuclide levels. However, the gamma logging data was not useful in quantifying radionuclide concentrations in the subsurface soil, because of the varying ratios of Ra-226, U-235, U-238, Th-232, and Cs-137 occurring in soils from this site.

Radionuclide Concentrations in Borehole Soil Samples

Table 7 presents the radionuclide concentrations measured in soil samples from boreholes. Neither the six boreholes (H1-H6), located to provide a representative coverage of the property, nor boreholes H7-H12, drilled in areas of elevated radiation levels identified by the walkover scan, contained radionuclide concentrations differing from the ranges in baseline samples.

Radionuclide Concentrations in Water

Surface Water

Samples W1-W4 from standing water on property D (refer to Table 8) contained gross alpha concentrations ranging from <1.68 to 5.05 pCi/l.

Gross beta concentrations ranged from 3.15–8.45 pCi/l. These values are within the EPA Drinking Water Standards of 15 pCi/l, gross alpha, and 50 pCi/l, gross beta.

Subsurface Water

Water samples collected from boreholes contained from 1.02 to 6.19 pCi/l of gross alpha and 5.52 to 65.4 pCi/l of gross beta. The sample from borehole H11 exceeds the EPA guideline of 50 pCi/l for gross beta. The remainder of the samples are within the EPA criteria with most having concentrations in the range of baseline levels. It should be noted that many of these samples contained high concentrations of dissolved solids. This necessitated the use of smaller volumes of water for gross alpha analysis, resulting in larger relative errors than are usually associated with this procedure.

Radionuclide Concentrations in Drainage Ditch Sediments

Concentrations in sediment samples, collected from ditches found on the eastern, central, and western portions of the property, are presented in Table 9. Levels of Ra-226, U-235, U-238, Cs-137, and Th-232 were all comparable with baseline concentrations.

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The guidelines applicable to cleanup of off-site properties at the Niagara Falls Storage Site are presented in Appendix B. Radiation levels and radionuclide concentrations, at small, isolated spots of surface or near-surface contamination, exceed these guideline values.

The exposure rates in contact with most of the isolated areas of surface contamination, exceed the guideline of 60 μR/h for open land areas accessible by the general public. The highest level measured was 3000 μR/h. (The object responsible for this radiation level was removed from the property by sample collection operations; however, other small locations of contact exposure rates exceeding 60 μR/h remain.) Exposure rates at 1 m above the surface are within the 60 μR/h guideline with the exception of an area near a metallic looking rock. The level at 1 m from this material was 110 μR/h.

Areas of surface contamination, identified by the walkover scan, contained Ra-226 concentrations in excess of 5 pCi/g; three of the samples also contained U-238 concentrations above the 150 pCi/g criterion. Most of these areas of contamination are small and isolated, and concentrations would be below the 5 pCi/g and 150 pCi/g guidelines if averaged over an area of 100 m^2. Many of the high radionuclide concentrations are associated with pieces of rock- or slag-type material. This material was noted primarily in the northwest and west central portions of the property and in areas of recent construction or earthmoving activities. Sampling also identified one piece of lead cake residue (Ra-226) and a Cs-137 "spark gap" device, each containing radionuclide levels exceeding the guidelines. (These objects were also removed by sampling.) Borehole measurements and samples did not identify subsurface levels differing from those in baseline samples.

Surface water contained radionuclide concentrations below the EPA limits of 15 pCi/l, gross alpha and 50 pCi/l, gross beta. None of the subsurface water samples contained gross alpha levels exceeding 15 pCi/l; however, sample W8, collected from borehole H11 at grid point 372N, 336E, did contain a gross beta concentration of 65.4 pCi/l. This sample was from an area identified by the walkover scan as having elevated direct radiation levels and several spots of isolated surface contamination. It should be noted that the EPA Drinking Water Standards are not applicable to sources of water which are not community water supplies. These standards are therefore presented only for comparison purposes and are not applicable to the water sources sampled on property E. Other borehole water samples indicate that radioactive residues on the property are not producing general ground water contamination.

SUMMARY

A comprehensive survey of off-site property D at the Niagara Falls Storage Site was conducted during May-August 1983. The survey included: surface radiation scans, measurements of direct radiation levels, and analyses for radionuclide concentrations in soil and water samples, both surface and subsurface. Analyses of sediment samples, collected at several locations, were also performed. Ground penetrating radar was used to identify subsurface utilities which might preclude borehole drilling.

The results of the survey indicated numerous, small, isolated areas of elevated direct radiation and surface soil contamination. The major contaminant was Ra-226; however, U-238, Th-232, and Cs-137 contamination was also noted. Most of these areas were associated with pieces of a rock-type material (possibly a chemical processing slag). This material was noted primarily in the northwest and west-central sections of the property and in areas of recent construction or earthmoving activity. Other objects, e.g. a "spark gap" device, lead cake, and a metallic-looking mass, were also identified as sources of elevated radiation levels. Many of the small isolated sources of radiation were removed by the survey sampling procedure; however, there was no attempt to remove all such sources. It is also possible that additional materials are present beneath the fill and piles of earth which have been accumulated in the section of the site (near 360N,320E). It is estimated that less than 2 m^3 of the rock-type material and other isolated objects with radionuclide levels exceeding the criteria, are present on this property. Locations of the remaining areas, noted by this survey, are listed in Table 10 and shown on Figure 8.

No subsurface contamination was identified and sampling indicates that contamination is not migrating from the property into surface or ground water systems.

Although the contaminated residues on small portions of this property exceed the guidelines established for release of the site for unrestricted use by the general public, the contaminants do not pose potential health risks to the public or site workers. There are continual construction and maintenance activities on this property and these activities have the potential for relocating, distributing, and concealing contaminated residues that were identified by this survey. During a visit to the property in November 1983 (after the survey had been completed), it was observed that additional earthmoving has occurred in the west-central portion of the property, the area where numerous isolated pieces of the contaminated rock-type material had been identified.

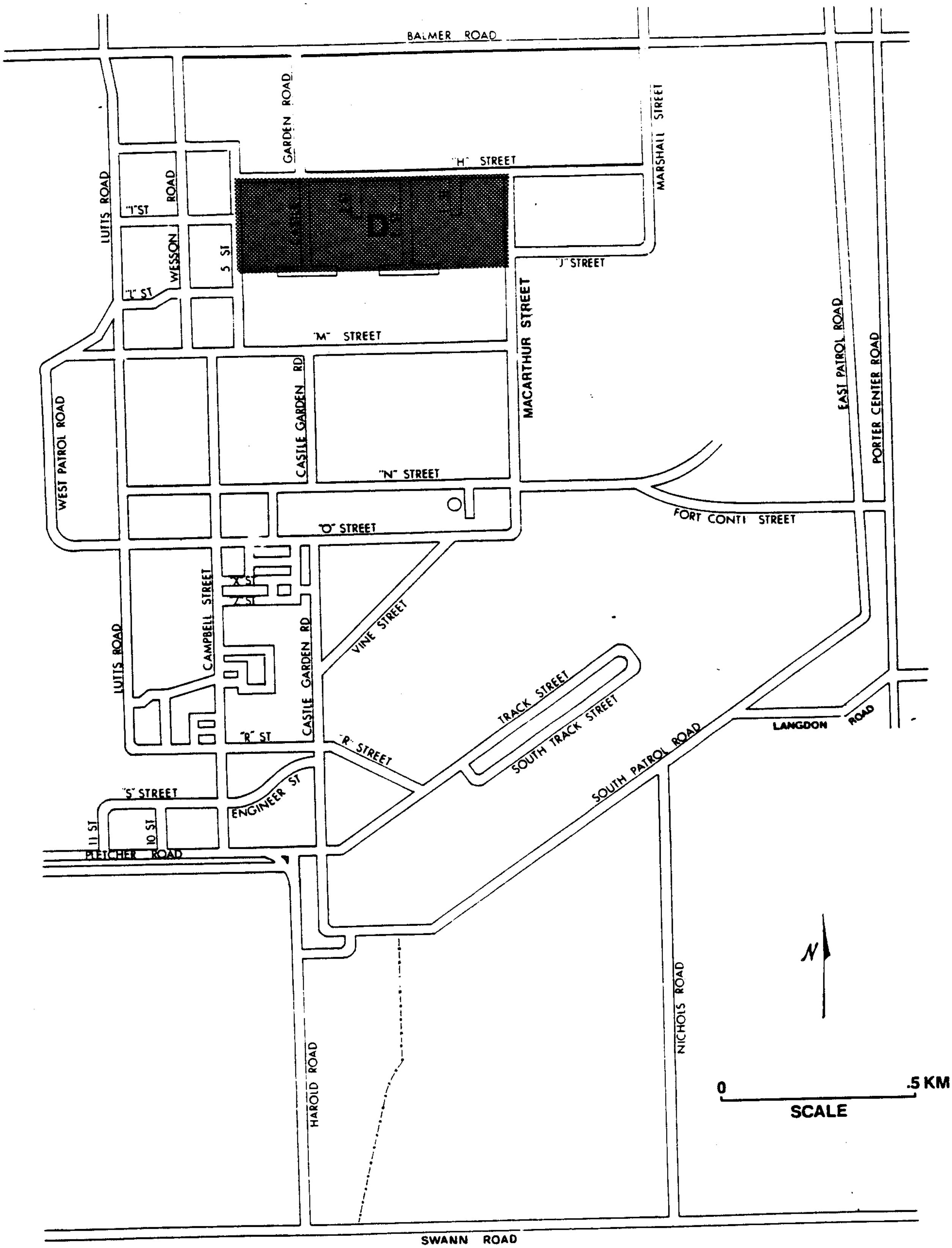

FIGURE 1. Map of Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property D.

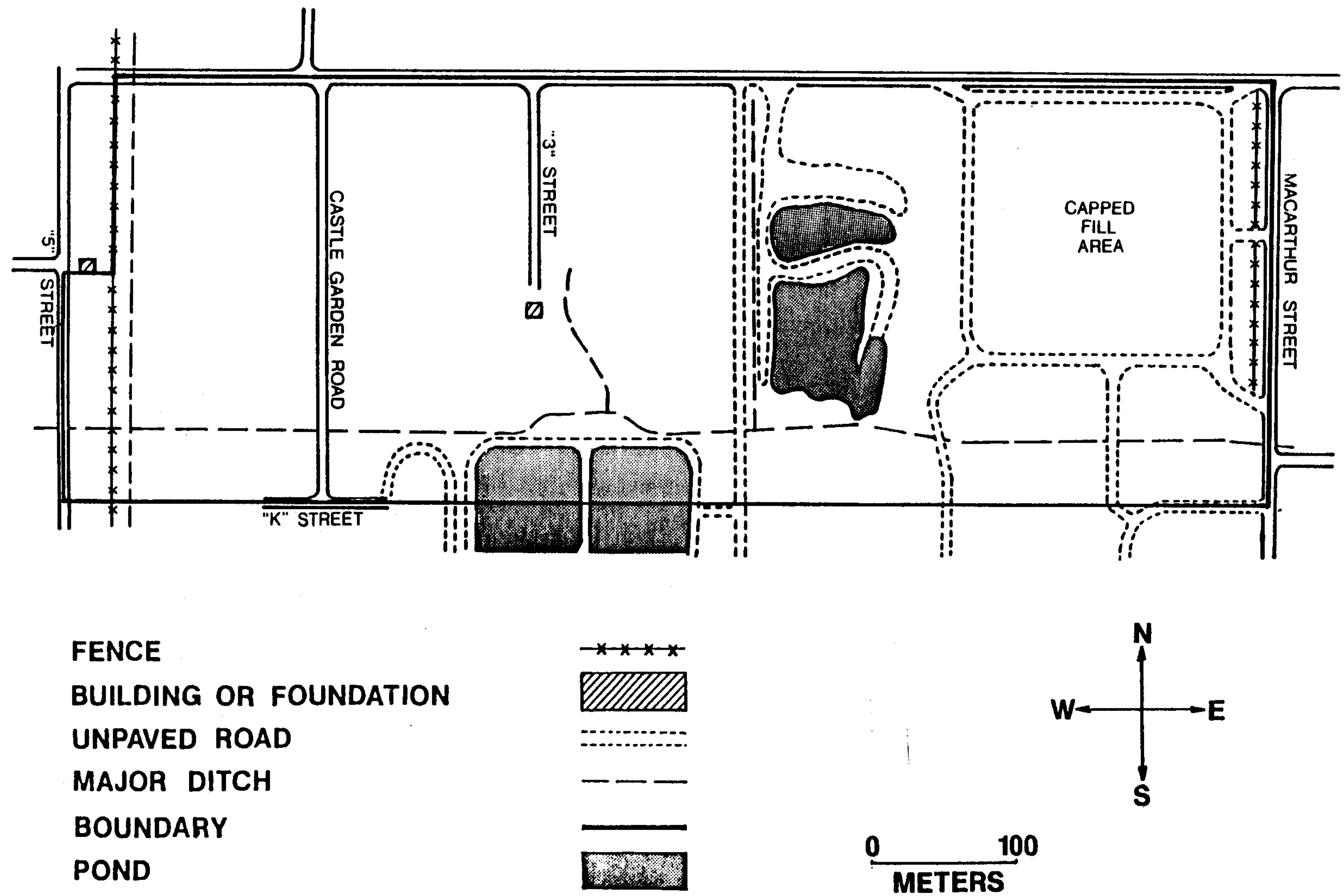

FIGURE 2. Plan View of NFSS Off-Site Property D Indicating Prominent Surface Features.

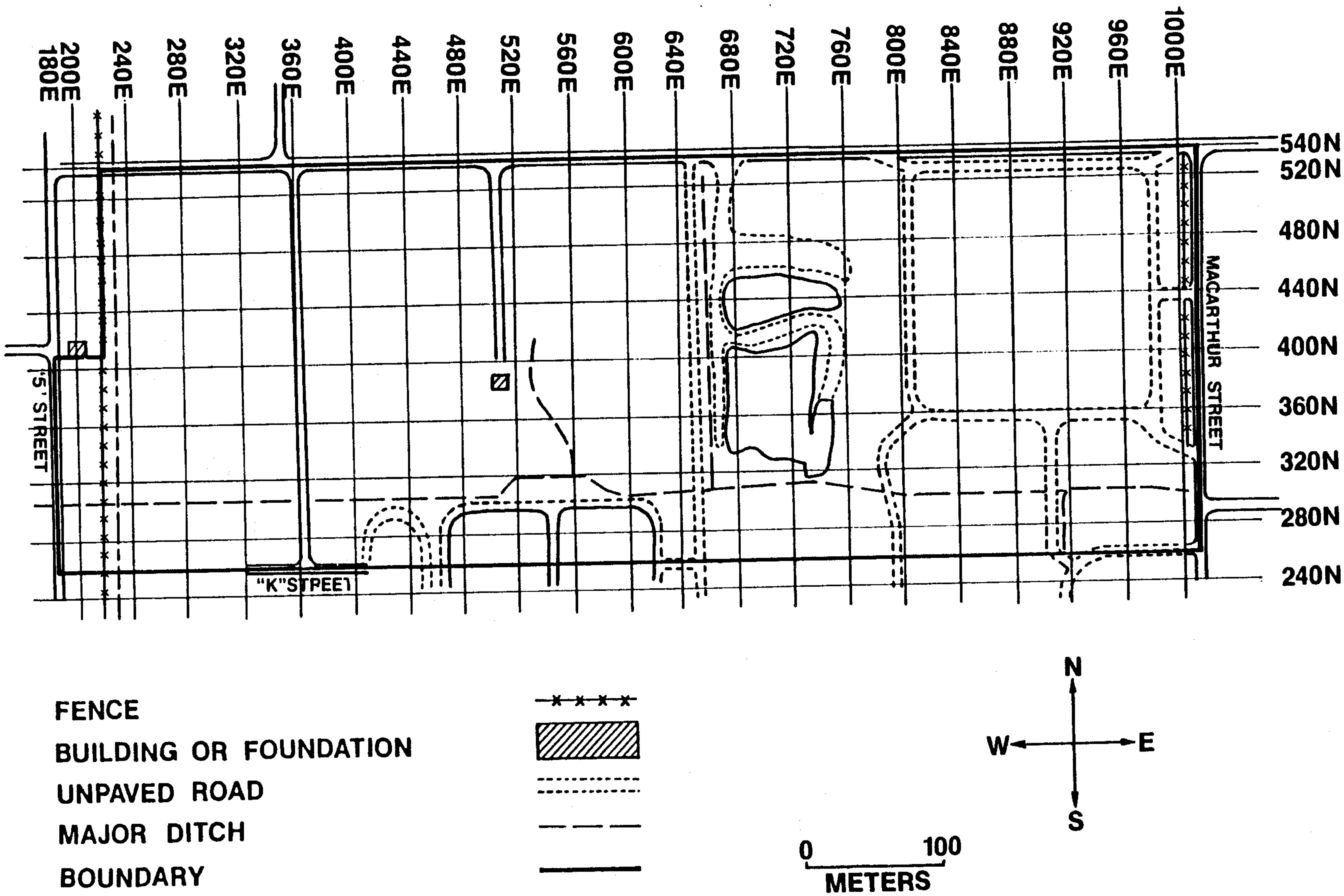

FIGURE 3. Plan View of NFSS Off-Site Property D Indicating the Grid System Established for Survey Reference.

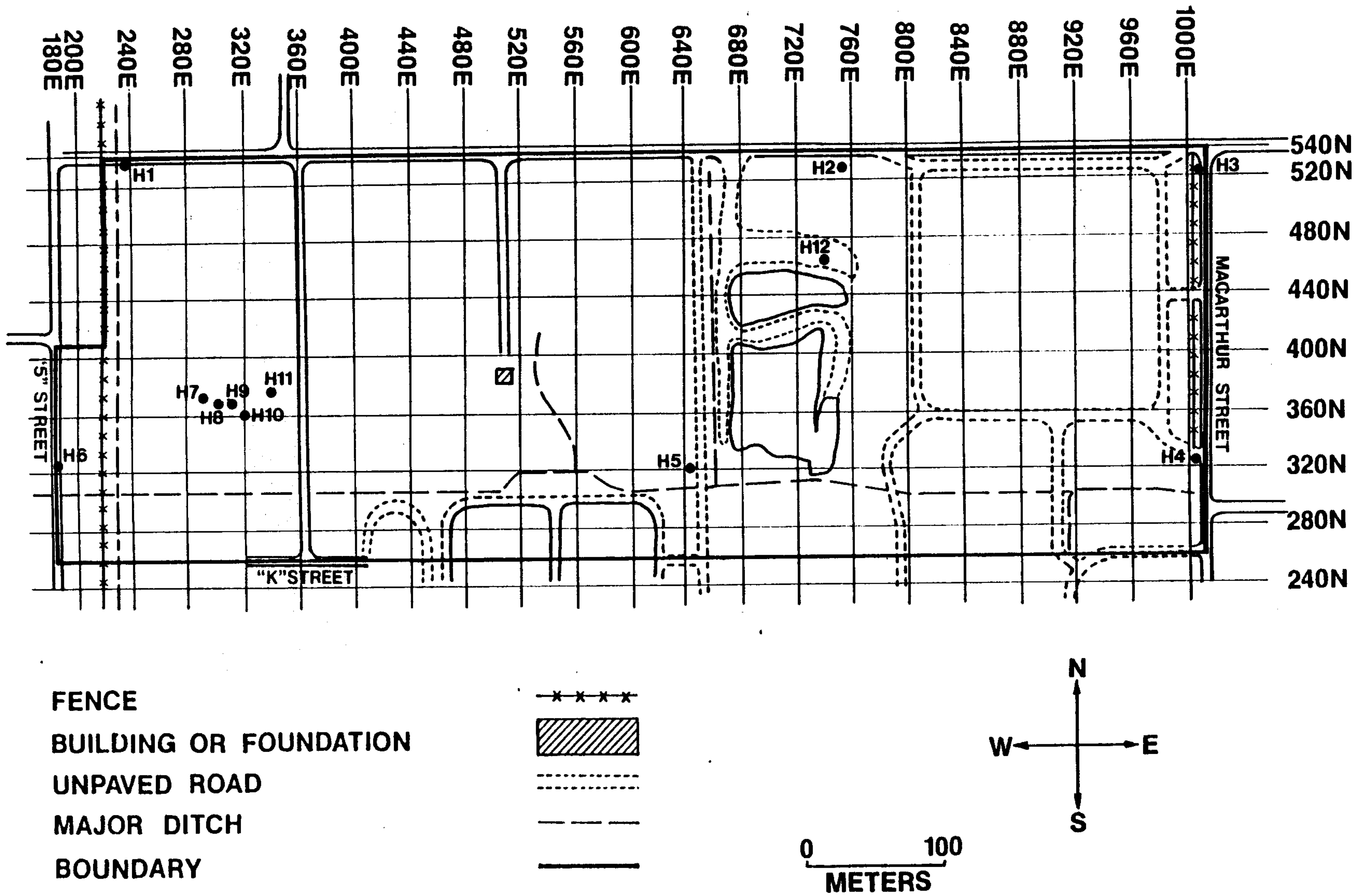

FIGURE 4. Locations of Boreholes for Subsurface Investigations.

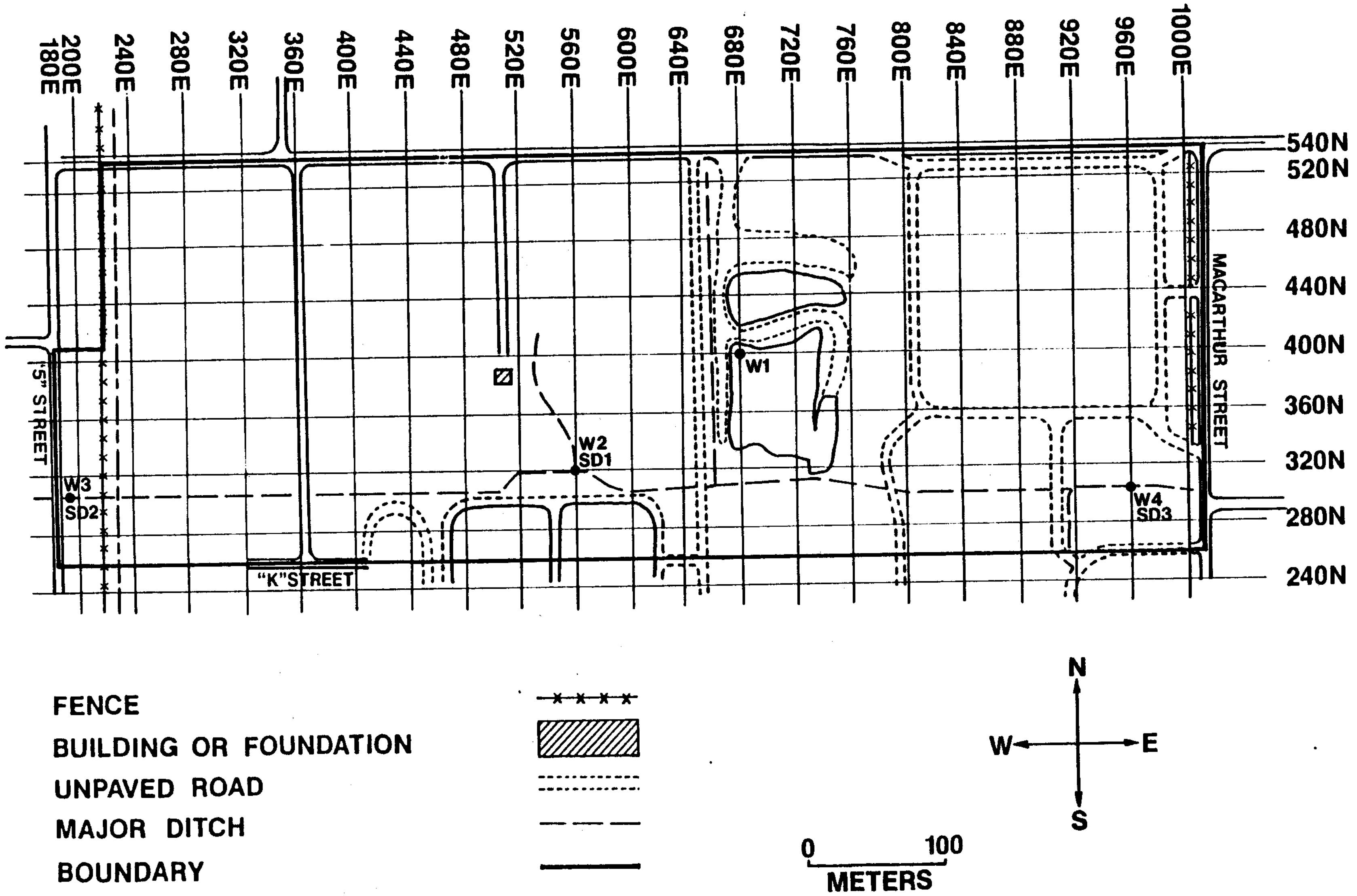

FIGURE 5. Locations of Water (W1-W4) and Sediment (SD1-SD3) Samples from Ponds and Ditches.

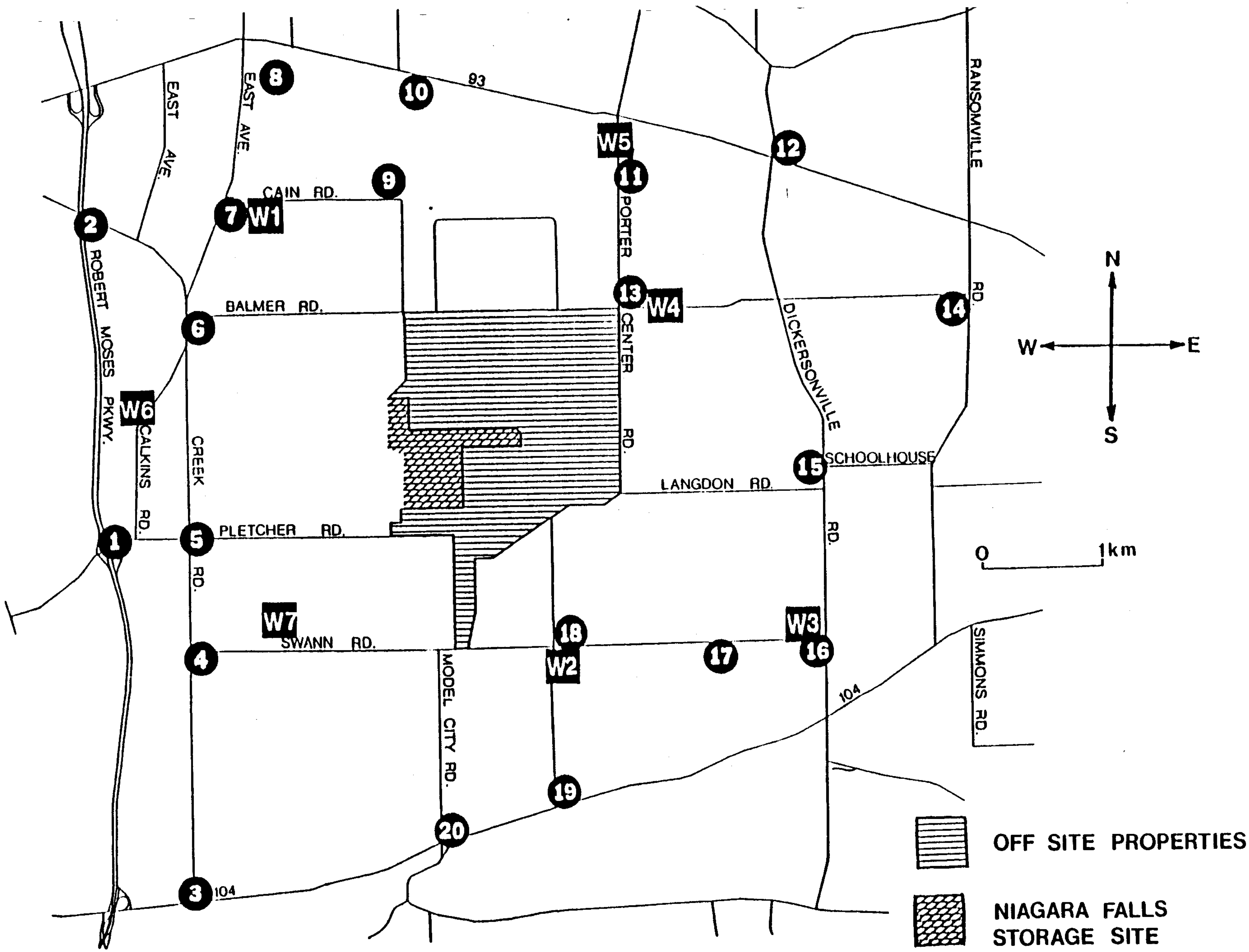

FIGURE 6. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples. (#1-20: soil samples and direct measurements; W1-W7: water samples.)

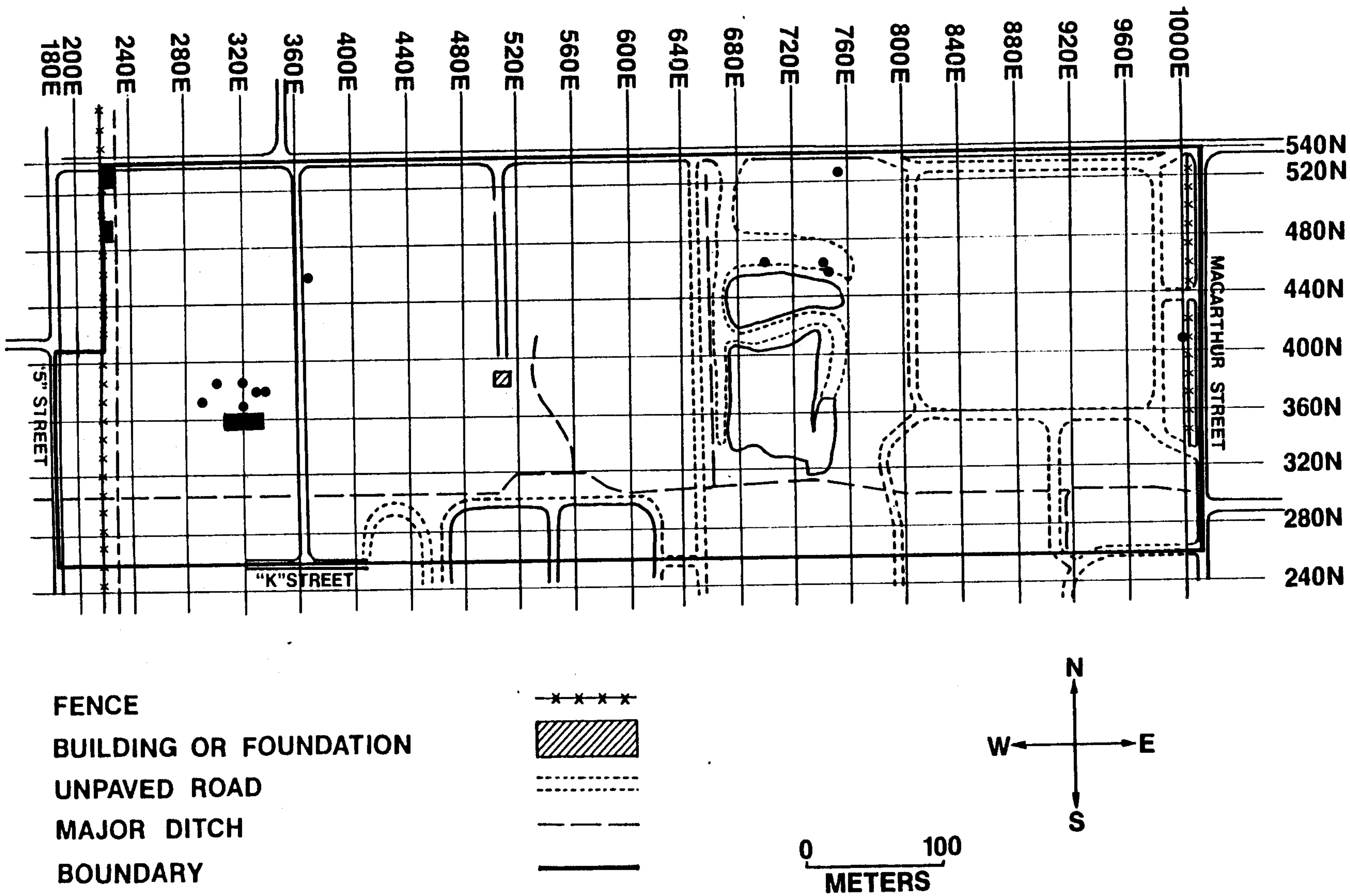

FIGURE 7. Locations of Areas of Elevated Direct Radiation. (Larger shaded areas indicate multiple locations in these regions.)

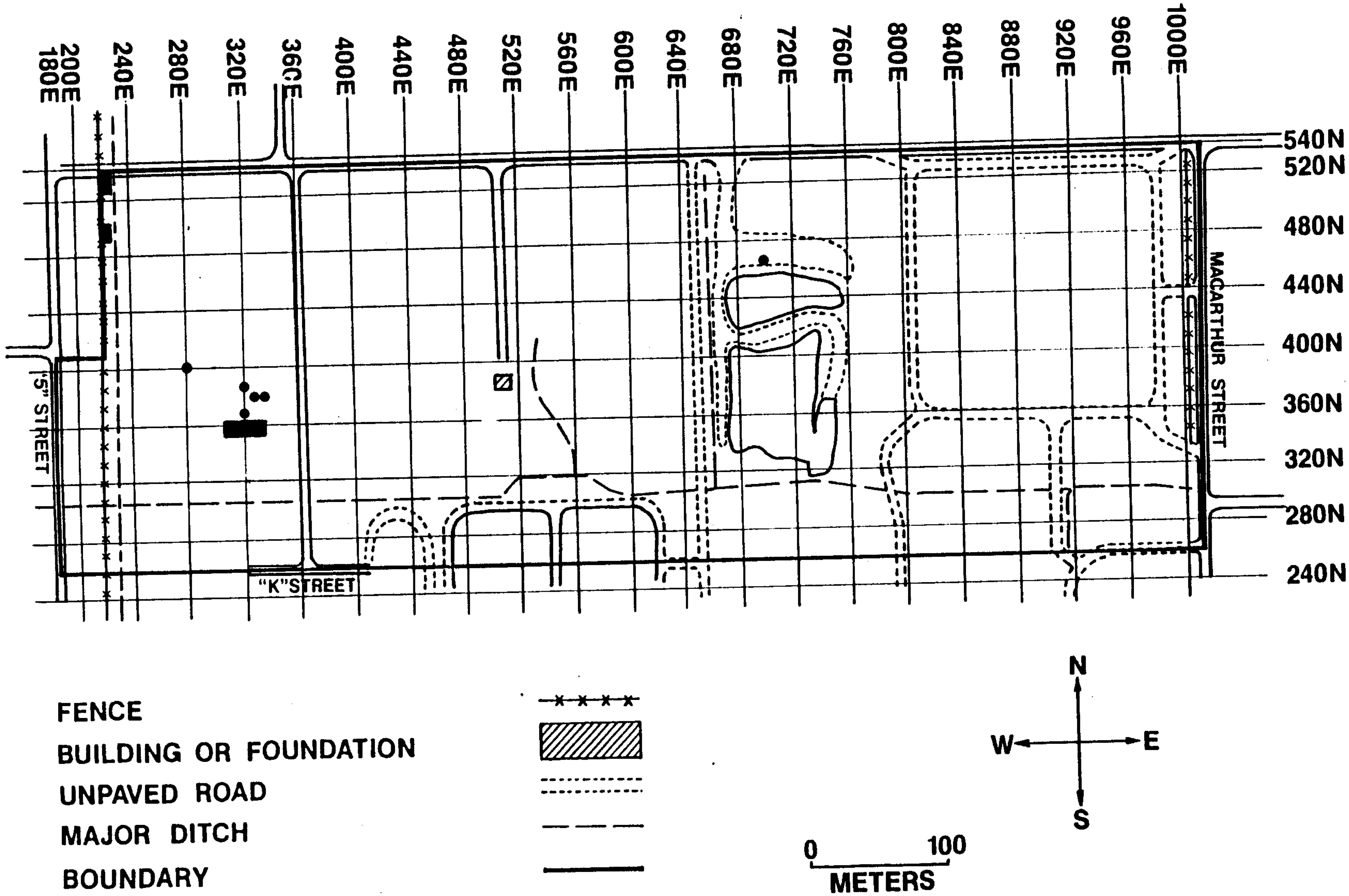

FIGURE 8. Map of NFSS Off-Site Property D Indicating Areas Where Radionuclide Concentrations in Soil Exceed Criteria Levels. (Larger shaded areas indicate multiple locations in these regions.)

TABLE 1-A

BACKGROUND EXPOSURE RATES
AND
RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL SAMPLES

Location[a]	Exposure Rate[b] (μR/h)	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Th-232	Cs-137
1	6.8	0.74 ± 0.16[c]	<0.19	<2.89	0.70 ± 0.46	0.29 ± 0.08
2	6.8	0.75 ± 0.19	<0.19	<3.35	0.86 ± 0.24	0.24 ± 0.08
3	8.3	0.71 ± 0.18	0.46 ± 0.41	<3.72	0.88 ± 0.33	0.34 ± 0.09
4	7.9	0.67 ± 0.18	<0.22	<4.10	1.18 ± 0.35	0.12 ± 0.07
5	7.3	0.70 ± 0.16	<0.17	<3.34	0.68 ± 0.24	0.35 ± 0.08
6	7.7	0.50 ± 0.15	<0.16	<2.33	0.52 ± 0.38	0.17 ± 0.09
7	7.7	0.63 ± 0.13	<0.17	<2.73	0.83 ± 0.24	0.35 ± 0.08
8	7.6	0.59 ± 0.12	<0.14	<2.20	0.54 ± 0.23	<0.02
9	7.1	0.63 ± 0.20	<0.23	<4.16	0.83 ± 0.38	0.69 ± 0.11
10	7.1	0.70 ± 0.16	<0.19	<2.98	0.59 ± 0.25	0.69 ± 0.10
11	6.7	<0.09	<0.19	<2.83	0.49 ± 0.31	0.48 ± 0.14
12	7.1	0.48 ± 0.13	<0.16	<2.84	0.65 ± 0.26	0.68 ± 0.10
13	6.7	0.57 ± 0.14	<0.17	<2.36	0.49 ± 0.26	0.41 ± 0.08
14	6.8	0.68 ± 0.17	<0.19	<3.24	0.67 ± 0.25	0.70 ± 0.10
15	8.2	0.65 ± 0.14	<0.17	<3.20	0.72 ± 0.35	0.23 ± 0.08
16	7.4	0.91 ± 0.17	<0.71	<3.58	0.83 ± 0.28	0.61 ± 0.09
17	7.0	0.48 ± 0.14	<0.16	<2.73	0.32 ± 0.22	0.38 ± 0.08
18	7.7	0.73 ± 0.16	<0.18	6.26 ± 9.23	1.01 ± 0.44	0.32 ± 0.12
19	8.8	1.22 ± 0.22	<0.23	<3.79	1.08 ± 0.49	1.05 ± 0.13
20	8.6	0.83 ± 0.17	<0.21	<3.59	0.84 ± 0.29	0.08 ± 0.07
Range	6.8 to 8.8	<0.09 to 1.22	<0.14 to 0.46	<2.20 to 6.26	0.32 to 1.18	<0.02 to 1.05

[a] Refer to Figure 6.
[b] Measured at 1 m above the surface.
[c] Errors are 2σ based on counting statistics.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Location[a]	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
W1	0.95 ± 0.93 [b]	4.79 ± 1.15
W2	0.95 ± 0.94	9.17 ± 1.31
W3	0.55 ± 0.78	2.73 ± 1.05
W4	0.63 ± 0.89	5.37 ± 1.17
W5	0.73 ± 0.68	<0.64
W6	1.87 ± 1.84	14.3 ± 2.4
W7	1.16 ± 0.66	<0.63
Range	0.55 to 1.87	<0.63 to 14.3

[a] Refer to Figure 6.
[b] Errors are 2σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
540	225	9	8	15
540	240	7	7	24
540	280	8	9	26
540	320	8	9	23
540	360	10	10	26
540	400	9	8	14
540	440	9	9	25
540	480	9	9	14
540	520	9	10	14
540	560	8	10	21
540	600	9	10	24
540	640	8	8	29
540	680	9	9	29
540	720	8	9	30
540	760	8	7	14
540	800	8	8	22
540	840	8	8	21
540	880	8	8	27
540	920	8	8	8
540	960	8	8	27
540	1000	7	7	17
540	1008	6	5	5
520	225	7	6	15
520	240	8	8	21
520	280	6	7	8
520	320	6	7	7
520	360	8	8	11
520	400	6	7	14
520	440	6	7	7
520	480	7	7	15
520	520	7	7	21
520	560	6	7	7
520	600	7	7	7
520	640	7	8	18
520	680	7	7	14
523	720	6	6	6
520	760	7	8	15
520	800	7	7	18

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
520	840	8	8	21
520	880	8	8	28
520	920	8	8	8
520	960	8	8	32
520	1000	7	7	7
520	1008	7	7	9
480	225	7	7	10
480	240	7	7	31
480	280	7	6	6
480	320	7	7	7
480	360	8	8	18
480	400	7	8	16
480	440	7	8	27
480	480	7	7	18
480	520	6	7	14
480	560	7	7	26
480	600	7	8	13
480	640	7	7	20
480	680	8	7	26
480	720	7	8	35
480	760	8	8	8
480	800	7	7	7
480	840	8	8	27
480	880	8	8	22
480	920	7	7	18
480	960	8	8	21
480	1000	7	7	9
480	1009	6	6	11
440	200	a	a	a
440	240	6	7	23
440	280	6	7	20
440	320	6	7	7
440	360	8	10	10
440	400	7	7	11
440	440	7	8	14
440	480	7	8	14
440	480	7	7	20

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
440	520	6	7	18
440	560	7	7	20
440	600	a	a	a
440	640	7	7	7
440	680	a	a	a
440	720	a	a	a
440	760	8	8	31
440	800	8	8	29
440	840	8	8	24
440	880	8	8	16
440	920	7	7	20
440	960	8	8	12
440	1000	7	7	17
400	200	7	7	24
400	240	7	7	15
400	280	7	8	16
400	320	7	7	10
400	360	9	10	10
400	400	7	7	15
400	440	8	8	8
400	480	7	7	17
400	520	7	7	26
400	560	7	7	13
400	600	7	7	24
400	640	7	7	27
400	675	7	6	19
400	720	a	a	a
400	760	8	8	15
400	800	8	8	17
400	840	7	8	21
400	880	8	8	28
400	920	7	8	9
400	960	8	7	7
400	1000	8	8	25
360	180	9	9	26
360	200	7	7	21
360	240	6	6	19

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
360	280	6	7	26
360	320	10	9	15
360	360	7	8	11
360	400	7	7	7
360	440	7	7	7
360	480	6	6	15
360	520	7	7	13
360	560	6	7	14
360	600	7	7	24
360	640	7	7	9
360	680	a	a	a
360	724	6	7	20
360	760	7	7	27
360	800	7	7	21
360	840	7	7	30
360	880	7	7	17
360	920	7	7	11
360	960	7	7	21
360	1000	7	7	15
360	1008	6	7	7
320	180	8	9	29
320	200	7	7	18
320	240	8	8	31
320	280	7	7	27
320	320	7	7	13
320	360	8	10	20
320	400	6	7	24
320	440	6	7	8
320	480	6	7	7
320	520	7	7	21
320	560	6	6	25
320	600	7	7	20
320	640	7	7	7
320	680	7	7	20
320	720	7	7	17
320	760	7	7	16
320	800	8	8	17
320	840	8	8	25

TABLE 2, cont.

DIRECT RADIATION LEVELS
MEASURED AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
320	880	8	8	24
320	920	8	8	22
320	960	7	7	17
320	1000	7	7	10
320	1008	6	7	15
280	180	6	6	6
280	200	7	8	12
280	240	7	7	13
280	280	7	7	21
280	320	7	7	26
280	360	8	8	18
280	400	7	7	27
280	440	7	7	20
297	480	7	7	7
295	520	7	7	7
295	560	7	7	9
295	600	7	7	26
280	640	8	7	20
280	680	7	8	21
280	720	8	8	11
280	760	7	7	12
280	800	7	8	19
280	840	7	7	7
280	880	7	7	13
280	920	7	7	27
280	960	7	7	12
280	1000	6	6	20
280	1008	6	6	6

a Measurement not taken due to construction or presence of standing water.

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Location[a]		Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Sample Identification[b]	Contact Exposure Rate After Sample Removal (μR/h)
N	E	Contact	1 m Above Surface			
539	222	44	13	100	B1A	90
538	222	46	14	49	B2A	27
538	222	140	14	1020	B2B	--[c]
536	224	38	10	38	B3	16
521	758	76	10	76	B4	10
493	221	40	17	90	B5	40
491	221	29	13	76	B6	--
465	740	140	10	220	B7	8
464	708	31	9	170	--	--
460	742	190	13	240	B8	9
458	364	170	9	1030	B9	12
407	989	72	8	210	B10	8
384	312	3000	21	3000	B11	8
384	320	68	9	68	--	--
380	328	44	8	44	--	--
380	330	59	10	59	--	--
376	292	2900	110	6450	B12	--
369	320	220	13	220	--	--
363	326	42	13	42	--	--
362	318	36	9	46	B13	12
362	322	52	12	88	--	--
361	310	220	14	220	--	--
361	323	68	13	68	--	--
361	325	56	13	56	--	--
360	299	48	13	69	B14	12
360	300	84	14	84	--	--
360	308	59	10	65	--	--
359	320	29	13	29	--	--
358	320	29	9	29	--	--
356	322	100	12	100	--	--
356	328	520	20	520	--	--
351	324	200	13	200	--	--

[a] Refer to Figure 7.
[b] Radionuclide analyses of samples presented in Tables 5 and 6.
[c] Dash indicates measurement or sampling not performed.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
535	240	1.05 ± 0.23[a]	<0.19	1.07 ± 1.58	0.10 ± 0.08	0.73 ± 0.45
537	280	0.74 ± 0.19	<0.20	<0.65	1.17 ± 0.16	0.87 ± 0.34
537	320	0.80 ± 0.19	<0.27	<0.93	0.95 ± 0.13	0.66 ± 0.58
535	360	0.69 ± 0.29	<0.17	1.54 ± 1.53	0.24 ± 0.10	0.59 ± 0.43
536	400	0.85 ± 0.19	<0.24	0.63 ± 2.08	0.59 ± 0.12	0.94 ± 0.53
535	440	0.95 ± 0.25	<0.17	1.29 ± 1.32	0.51 ± 0.11	<0.23
537	480	1.01 ± 0.21	<0.16	0.65 ± 0.42	0.48 ± 0.10	0.66 ± 0.23
536	520	0.91 ± 0.20	<0.29	1.53 ± 0.99	0.31 ± 0.10	1.07 ± 0.24
535	560	1.05 ± 0.24	0.37 ± 0.40	0.99 ± 0.61	0.22 ± 0.09	0.90 ± 0.35
536	600	0 78 ± 0.16	<0.18	<0.78	0.43 ± 0.11	0.50 ± 0.35
536	640	1.00 ± 0.19	0.14 ± 0.77	<0.75	0.21 ± 0.09	0.58 ± 0.30
536	680	0.94 ± 0.21	<0.18	1.08 ± 1.54	0.07 ± 0.09	0.56 ± 0.34
536	720	0.89 ± 0.25	<0.18	<0.67	0.16 ± 0.07	0.73 ± 0.26
538	760	2.44 ± 0.31	<0.17	<0.75	<0.04	0.40 ± 0.32
540	800	0.71 ± 0.21	<0.16	0.50 ± 0.44	<0.03	0.87 ± 0.31
539	840	0.96 ± 0.18	<0.28	1.26 ± 1.47	<0.04	1.59 ± 0.45
540	880	0.89 ± 0.26	<0.21	<0.66	<0.03	0.80 ± 0.33
540	920	0.83 ± 0.21	<0.27	<0.85	<0.03	1.35 ± 0.31
540	960	0.83 ± 0.29	<0.16	0.78 ± 0.99	<0.03	0.86 ± 0.26
539	1000	0.98 ± 0.23	<0.20	0.87 ± 1.50	<0.04	0.72 ± 0.36
520	220	0.81 ± 0.21	<0.32	1.54 ± 2.0	0.99 ± 0.16	0.94 ± 0.36
520	240	0.84 ± 0.25	<0.21	<0.81	<0.04	0.88 ± 0.43
520	280	0.55 ± 0.19	<0.18	1.16 ± 2.19	0.68 ± 0.14	1.00 ± 0.36
520	320	0.61 ± 0.19	<0.16	<0.85	0.90 ± 0.17	0.54 ± 0.25
520	360	0.89 ± 0.20	<0.16	0.89 ± 0.82	0.09 ± 0.08	0.72 ± 0.26
520	400	0.69 ± 0.20	<0.19	<0.71	0.57 ± 0.12	0.61 ± 0.40
520	440	0.48 ± 0.20	<0.16	1.57 ± 1.20	0.98 ± 0.15	0.77 ± 0.48
520	480	0.68 ± 0.28	<0.30	0.57 ± 0.67	0.63 ± 0.12	0.90 ± 0.30
520	520	0.86 ± 0.26	<0.15	0.79 ± 0.41	0.23 ± 0.07	0.75 ± 0.36
520	560	1.00 ± 0.38	<0.43	2.60 ± 2.18	1.05 ± 0.18	1.84 ± 0.75
520	600	0.81 ± 0.28	<0.29	2.42 ± 2.00	0.75 ± 0.18	<0.23
520	640	0.79 ± 0.20	<0.18	<0.63	0.20 ± 0.07	0.81 ± 0.40
520	680	0.71 ± 0.30	<0.19	0.84 ± 1.87	0.19 ± 0.09	0.68 ± 0.43
523	720	0.76 ± 0.23	<0.18	1.23 ± 0.57	0.66 ± 0.14	0.57 ± 0.33
520	760	1.00 ± 0.25	<0.20	<0.78	0.08 ± 0.08	0.89 ± 0.39
520	800	1.63 ± 0.28	<0.25	0.83 ± 1.52	0.16 ± 0.07	0.89 ± 0.29
520	840	0.84 ± 0.20	<0.14	0.56 ± 0.44	<0.02	0.74 ± 0.36
520	880	1.13 ± 0.21	<0.29	5.03 ± 1.74	<0.03	0.82 ± 0.41
520	920	0.96 ± 0.24	<0.18	<0.69	<0.03	1.04 ± 0.29

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
520	960	1.33 ± 0.24	<0.30	2.21 ± 0.93	<0.04	1.01 ± 0.30
520	1000	1.03 ± 0.23	<0.29	<0.95	0.61 ± 0.16	1.34 ± 0.71
520	1004	0.60 ± 0.21	<0.19	1.31 ± 1.17	0.05 ± 0.08	0.66 ± 0.32
480	220	0.69 ± 0.33	<0.19	<0.73	0.55 ± 0.14	0.76 ± 0.40
480	240	0.68 ± 0.24	<0.18	<0.80	<0.03	0.66 ± 0.59
480	280	0.56 ± 0.16	<0.28	<0.88	0.73 ± 0.13	1.04 ± 0.39
480	320	0.71 ± 0.18	<0.17	1.15 ± 0.46	0.73 ± 0.13	0.66 ± 0.32
480	360	0.63 ± 0.29	<0.18	1.51 ± 1.02	0.75 ± 0.07	0.63 ± 0.36
480	400	0.90 ± 0.21	<0.26	2.17 ± 1.02	0.36 ± 0.10	0.85 ± 0.44
480	440	0.61 ± 0.21	<0.14	1.19 ± 0.41	<0.03	1.05 ± 0.25
480	480	0.85 ± 0.19	0.60 ± 0.43	1.44 ± 0.93	0.30 ± 0.01	1.01 ± 0.45
480	520	0.68 ± 0.18	<0.24	<0.73	<0.03	1.04 ± 0.30
480	560	0.76 ± 0.26	<0.19	<0.73	<0.02	0.91 ± 0.39
480	600	0.76 ± 0.19	<0.14	0.94 ± 0.39	<0.03	0.95 ± 0.30
480	640	0.86 ± 0.29	<0.15	0.49 ± 0.64	0.09 ± 0.08	0.62 ± 0.40
480	680	0.71 ± 0.16	<0.13	0.95 ± 0.42	0.04 ± 0.06	0.77 ± 0.26
480	720	0.83 ± 0.24	<0.18	0.92 ± 1.79	0.08 ± 0.08	1.05 ± 0.32
480	760	1.08 ± 0.19	<0.26	1.35 ± 1.63	0.11 ± 0.06	0.92 ± 0.36
480	800	0.91 ± 0.26	<0.18	1.06 ± 0.76	0.09 ± 0.15	0.91 ± 0.36
480	840	1.25 ± 0.26	<0.28	<0.89	<0.03	0.97 ± 0.36
480	880	1.20 ± 0.29	<0.16	1.35 ± 0.48	0.06 ± 0.05	0.91 ± 0.37
480	920	0.94 ± 0.20	<0.17	0.79 ± 0.46	<0.03	0.73 ± 0.46
480	960	1.08 ± 0.26	<0.17	<0.38	<0.03	1.05 ± 0.37
480	1000	0.90 ± 0.28	<0.18	1.47 ± 0.62	0.88 ± 0.16	0.79 ± 0.31
480	1005	0.88 ± 0.19	<0.23	3.20 ± 1.07	0.14 ± 0.08	0.81 ± 0.27
440	220	0.70 ± 0.18	<0.17	0.89 ± 0.73	0.46 ± 0.09	0.73 ± 0.29
440	240	0.80 ± 0.18	<0.28	1.20 ± 1.77	0.45 ± 0.11	1.31 ± 0.40
440	280	0.59 ± 0.18	<0.23	<0.72	0.76 ± 0.14	0.58 ± 0.30
440	320	0.99 ± 0.19	0.06 ± 0.08	1.79 ± 1.22	0.05 ± 0.04	0.55 ± 0.30
440	360	0.80 ± 0.21	<0.26	1.31 ± 1.73	0.13 ± 0.07	0.84 ± 0.33
440	400	0.80 ± 0.23	<0.25	1.34 ± 1.10	<0.03	0.64 ± 0.20
440	440	0.80 ± 0.26	<0.19	<0.64	<0.02	0.76 ± 0.24
440	480	0.64 ± 0.24	<0.14	0.94 ± 0.43	0.08 ± 0.06	0.86 ± 0.32
440	520	0.84 ± 0.26	<0.27	2.75 ± 1.07	0.07 ± 0.08	1.00 ± 0.36
440	560	0.78 ± 0.20	<0.18	<0.64	<0.03	0.83 ± 0.26
445	600	0.79 ± 0.18	<0.15	0.76 ± 1.16	<0.03	1.01 ± 0.35
440	640	0.66 ± 0.26	<0.18	1.12 ± 1.54	<0.04	0.91 ± 0.28
455	680	2.34 ± 0.34	<0.25	<0.93	<0.03	0.83 ± 0.51
440	720	b	b	b	b	b
440	760	0.81 ± 0.21	<0.16	<0.77	<0.03	0.60 ± 0.41

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
440	800	0.73 ± 0.25	<0.20	<0.83	0.07 ± 0.11	1.28 ± 0.34
440	840	0.75 ± 0.24	<0.25	<0.81	<0.04	0.94 ± 0.30
440	880	0.74 ± 0.23	<0.18	1.16 ± 1.43	<0.04	0.78 ± 0.29
440	920	1.14 ± 0.23	<0.30	1.76 ± 1.48	0.30 ± 0.10	0.88 ± 0.28
440	960	1.14 ± 0.34	<0.28	1.67 ± 1.29	<0.04	1.02 ± 0.54
440	1000	1.23 ± 0.20	<0.15	0.62 ± 0.34	<0.04	0.65 ± 0.30
440	1005	0.83 ± 0.26	<0.16	<0.75	<0.04	0.72 ± 0.32
420	176	1.40 ± 0.30	<0.23	1.75 ± 1.96	1.18 ± 0.15	0.43 ± 0.26
420	280	0.68 ± 0.24	0.03 ± 0.04	<).88	0.67 ± 0.13	1.23 ± 0.36
420	320	0.75 ± 0.35	<0.21	1.11 ± 1.45	0.38 ± 0.14	0.79 ± 0.36
420	680	0.75 ± 0.24	<0.25	1.49 ± 1.22	<0.03	0.88 ± 0.52
425	720	0.74 ± 0.24	<0.16	0.91 ± 0.39	<0.03	0.82 ± 0.24
400	177	1.01 ± 0.24	<0.18	0.86 ± 1.43	0.74 ± 0.12	0.68 ± 0.32
400	200	0.80 ± 0.24	<0.30	<1.01	0.36 ± 0.10	0.89 ± 0.28
400	220	0.90 ± 0.25	<0.20	<0.83	0.59 ± 0.11	0.74 ± 0.25
400	240	0.63 ± 0.24	<0.18	1.23 ± 1.52	0.15 ± 0.10	0.80 ± 0.26
400	260	0.85 ± 0.21	<0.14	1.14 ± 0.49	0.16 ± 0.08	0.96 ± 0.26
400	280	0.78 ± 0.21	<0.15	0.59 ± 0.78	0.73 ± 0.13	0.69 ± 0.32
400	300	0.70 ± 0.31	<0.17	<0.69	0.09 ± 0.10	0.35 ± 0.38
400	320	0.66 ± 0.18	<0.15	0.57 ± 0.38	0.15 ± 0.05	0.55 ± 0.23
400	340	0.79 ± 0.18	<0.18	<0.69	<0.03	1.06 ± 0.34
400	360	<0.16	<0.15	1.09 ± 1.29	0.13 ± 0.05	0.50 ± 0.45
400	400	0.55 ± 0.24	<0.17	1.33 ± 1.29	<0.03	0.78 ± 0.33
400	440	0.89 ± 0.20	<0.14	1.30 ± 0.43	<0.02	0.79 ± 0.28
400	480	0.66 ± 0.23	<0.13	0.81 ± 0.60	0.07 ± 0.04	0.63 ± 0.28
400	520	0.73 ± 0.18	<0.13	0.85 ± 0.62	0.02 ± 0.03	0.64 ± 0.19
400	560	2.08 ± 0.26	<0.25	0.86 ± 1.13	<0.03	0.82 ± 0.28
400	600	0.61 ± 0.26	<0.27	4.48 ± 1.59	<0.03	1.07 ± 0.36
400	640	0.63 ± 0.19	<0.19	0.95 ± 1.37	<0.03	1.12 ± 0.43
400	740	0.83 ± 0.19	<0.24	8.40 ± 1.41	<0.03	0.95 ± 0.31
400	760	0.94 ± 0.24	<0.19	1.26 ± 1.33	<0.04	0.78 ± 0.35
400	800	0.85 ± 0.20	0.22 ± 0.29	0.71 ± 0.44	0.14 ± 0.05	0.56 ± 0.48
400	800	0.91 ± 0.21	0.14 ± 0.36	1.15 ± 0.71	<0.03	0.85 ± 0.31
400	840	0.80 ± 0.26	<0.20	<0.69	<0.03	1.02 ± 0.28
400	880	b	b	b	b	b
400	920	0.93 ± 0.26	<0.20	1.46 ± 1.36	<0.03	0.74 ± 0.46
400	960	0.81 ± 0.24	<0.18	<0.63	<0.04	0.66 ± 0.42
400	1000	0.79 ± 0.21	<0.22	<0.77	0.52 ± 0.11	0.55 ± 0.42
400	1004	0.65 ± 0.21	<0.18	<0.63	0.08 ± 0.06	0.58 ± 0.27

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
380	260	0.58 ± 0.28	<0.20	1.99 ± 2.19	0.91 ± 0.16	1.10 ± 0.36
380	280	0.69 ± 0.24	0.16 ± 0.12	1.30 ± 1.34	0.11 ± 0.05	0.96 ± 0.34
380	300	0.89 ± 0.29	<0.28	1.44 ± 1.75	0.20 ± 0.08	1.11 ± 0.40
380	320	0.91 ± 0.24	<0.27	1.96 ± 1.10	0.22 ± 0.12	1.23 ± 0.30
380	340	0.64 ± 0.18	<0.18	<0.17	<0.04	0.68 ± 0.31
360	177	0.85 ± 0.35	<0.22	<0.73	0.56 ± 0.13	0.72 ± 0.36
360	200	0.55 ± 0.29	<0.23	1.60 ± 1.59	0.60 ± 0.13	0.73 ± 0.42
360	220	0.66 ± 0.25	<0.21	1.79 ± 1.84	0.66 ± 0.13	0.67 ± 0.36
360	240	0.64 ± 0.19	<0.17	1.10 ± 0.68	<0.02	0.69 ± 0.29
360	260	0.93 ± 0.26	0.25 ± 0.15	1.99 ± 1.61	0.24 ± 0.09	1.32 ± 0.41
360	280	0.70 ± 0.23	<0.16	0.97 ± 1.15	0.15 ± 0.06	0.88 ± 0.31
360	300	0.94 ± 0.25	<0.21	<0.72	<0.04	1.19 ± 0.41
360	320	1.03 ± 0.20	<0.16	0.29 ± 0.47	0.04 ± 0.06	0.94 ± 0.27
360	340	1.04 ± 0.24	<0.29	<0.86	<0.04	1.23 ± 0.35
360	360	0.99 ± 0.24	<0.16	1.13 ± 0.79	0.08 ± 0.04	0.47 ± 0.41
360	400	0.73 ± 0.26	<0.24	<0.76	<0.03	1.15 ± 0.28
360	440	0.71 ± 0.25	<0.19	1.35 ± 1.59	<0.03	1.07 ± 0.37
360	480	0.43 ± 0.13	<0.14	0.94 ± 1.13	<0.03	0.55 ± 0.30
360	520	0.68 ± 0.21	<0.14	0.67 ± 0.41	0.19 ± 0.07	0.77 ± 0.51
360	540	0.74 ± 0.21	<0.14	0.90 ± 0.40	<0.03	0.89 ± 0.29
360	560	0.94 ± 0.25	<0.26	1.75 ± 1.38	0.10 ± 0.07	0.95 ± 0.32
360	600	0.80 ± 0.21	<0.16	<0.55	<0.03	0.73 ± 0.34
360	640	0.71 ± 0.23	<0.17	<0.67	<0.03	0.68 ± 0.37
360	675	0.61 ± 0.16	<0.19	0.70 ± 1.25	<0.03	0.73 ± 0.27
360	720	b	b	b	b	b
360	760	0.58 ± 0.19	<0.17	<0.55	0.04 ± 0.07	0.74 ± 0.58
360	800	1.04 ± 0.34	0.11 ± 0.08	1.10 ± 1.24	0.19 ± 0.10	1.39 ± 0.40
360	840	1.10 ± 0.20	<0.23	1.07 ± 0.68	<0.03	1.18 ± 0.57
360	880	0.99 ± 0.25	0.02 ± 0.03	1.36 ± 1.60	<0.03	0.87 ± 0.38
360	920	0.90 ± 0.20	<0.19	<0.81	<0.04	1.17 ± 0.34
360	960	0.69 ± 0.28	<0.22	1.11 ± 1.76	<0.04	0.92 ± 0.34
360	1000	0.78 ± 0.24	<0.17	0.82 ± 1.51	0.44 ± 0.14	0.65 ± 0.38
360	1004	0.93 ± 0.21	<0.26	0.32 ± 1.55	<0.04	0.71 ± 0.29
340	260	0.88 ± 0.29	<0.29	1.97 ± 2.07	0.94 ± 0.13	1.42 ± 0.33
340	280	0.86 ± 0.24	<0.20	1.20 ± 1.48	0.14 ± 0.10	0.66 ± 0.25
340	300	1.21 ± 0.28	<0.29	<0.90	<0.03	1.14 ± 0.39
340	320	0.96 ± 0.25	<0.18	1.11 ± 1.75	<0.03	0.76 ± 0.34
340	340	0.89 ± 0.34	<0.20	1.69 ± 2.27	2.17 ± 0.24	0.83 ± 0.41
320	183	0.91 ± 0.34	<0.22	0.96 ± 0.89	0.60 ± 0.15	0.37 ± 0.21
320	200	0.85 ± 0.21	<0.25	2.48 ± 2.13	0.17 ± 0.07	1.24 ± 0.36

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES FROM 40 M GRID INTERVALS

Grid Location N	Grid Location E	Ra-226	U-235	U-238	Cs-137	Th-232
		Radionuclide Concentrations (pCi/g)				
320	220	0.65 ± 0.31	<0.21	<0.80	0.82 ± 0.18	0.50 ± 0.63
320	240	0.76 ± 0.18	<0.26	0.75 ± 1.55	<0.04	0.82 ± 0.35
320	260	0.91 ± 0.28	<0.21	1.56 ± 1.53	0.27 ± 0.12	1.19 ± 0.39
320	280	1.01 ± 0.26	<0.19	0.94 ± 1.42	.37 ± 0.11	0.80 ± 0.39
320	320	0.76 ± 0.23	<0.20	1.85 ± 1.37	0.11 ± 0.08	0.82 ± 0.27
320	358	0.78 ± 0.23	<0.16	0.76 ± 1.58	0.14 ± 0.09	0.78 ± 0.50
320	400	0.69 ± 0.23	<0.19	<0.70	<0.04	1.15 ± 0.32
320	440	0.88 ± 0.21	<0.16	<0.65	0.06 ± 0.06	0.65 ± 0.25
320	480	0.50 ± 0.19	<0.14	<0.48	0.05 ± 0.04	0.42 ± 0.26
320	520	0.91 ± 0.24	<0.19	0.89 ± 1.82	0.09 ± 0.09	0.92 ± 0.36
320	560	0.75 ± 0.19	<0.14	0.44 ± 0.68	<0.03	0.69 ± 0.29
320	600	0.86 ± 0.23	<0.26	0.61 ± 1.21	0.12 ± 0.05	1.16 ± 0.48
320	640	0.74 ± 0.19	<0.16	<0.57	0.14 ± 0.05	0.71 ± 0.21
320	680	0.86 ± 0.19	0.15 ± 0.08	2.07 ± 1.36	<0.02	1.01 ± 0.36
320	720	0.98 ± 0.28	<0.25	1.10 ± 1.14	<0.04	0.79 ± 0.30
320	760	1.23 ± 0.24	<0.22	1.06 ± 1.68	0.09 ± 0.05	1.43 ± 0.47
320	800	1.20 ± 0.26	<0.30	1.65 ± 1.74	<0.04	0.99 ± 0.55
320	840	0.88 ± 0.29	<0.20	<0.64	<0.03	0.83 ± 0.40
320	880	0.80 ± 0.25	<0.19	<0.83	<0.04	0.90 ± 0.35
320	920	0.63 ± 0.25	<0.21	<0.76	<0.03	1.09 ± 0.37
320	960	0.94 ± 0.28	<0.16	0.59 ± 0.80	0.02 ± 0.03	0.68 ± 0.32
320	1000	0.91 ± 0.26	<0.20	2.18 ± 1.00	0.71 ± 0.16	0.72 ± 0.31
320	1009	0.85 ± 0.16	0.40 ± 0.30	1.24 ± 0.38	0.07 ± 0.05	0.74 ± 0.20
300	480	0.74 ± 0.18	<0.15	1.30 ± 0.47	<0.03	0.98 ± 0.28
300	520	0.79 ± 0.25	<0.21	1.11 ± 1.22	0.16 ± 0.06	0.81 ± 0.35
300	560	0.94 ± 0.24	<0.24	<0.76	0.07 ± 0.08	0.84 ± 0.29
300	600	0.83 ± 0.26	<0.18	<0.72	0.04 ± 0.07	0.98 ± 0.34
280	183	1.13 ± 0.38	<0.28	0.99 ± 0.79	0.70 ± 0.11	0.64 ± 0.34
280	200	0.78 ± 0.26	<0.18	2.09 ± 1.40	0.08 ± 0.07	0.69 ± 0.41
280	240	1.06 ± 0.30	<0.32	1.27 ± 1.88	0.68 ± 0.14	0.98 ± 0.43
280	280	1.01 ± 0.26	<0.29	1.20 ± 2.60	0.37 ± 0.10	1.21 ± 0.39
280	320	1.00 ± 0.25	<0.29	7.65 ± 1.82	0.21 ± 0.16	0.83 ± 0.40
280	358	1.00 ± 0.26	<0.20	1.32 ± 1.45	0.74 ± 0.11	0.76 ± 0.39
280	400	0.81 ± 0.20	<0.25	<0.84	0.51 ± 0.14	0.82 ± 0.29
280	440	0.80 ± 0.23	<0.19	1.21 ± 1.24	<0.04	0.89 ± 0.28
280	480	b	b	b	b	b
280	520	b	b	b	b	b
280	560	b	b	b	b	b
280	600	b	b	b	b	b
280	640	0.88 ± 0.20	<0.19	0.95 ± 1.67	0.06 ± 0.07	0.74 ± 0.25

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
280	680	0.95 ± 0.23	<0.19	1.46 ± 1.45	0.06 ± 0.08	0.78 ± 0.40
280	720	1.09 ± 0.20	<0.26	0.97 ± 1.43	<0.04	0.93 ± 0.32
280	760	0.73 ± 0.21	<0.18	1.44 ± 1.57	<0.03	0.84 ± 0.35
280	800	0.80 ± 0.20	<0.26	3.66 ± 1.[illegible]7	0.07 ± 0.07	0.78 ± 0.26
280	840	0.99 ± 0.26	<0.26	0.92 ± 1.09	<0.03	1.07 ± 0.34
280	880	0.88 ± 0.21	<0.18	0.81 ± 1.43	<0.03	0.89 ± 0.26
280	920	1.04 ± 0.31	<0.25	1.23 ± 1.36	0.09 ± 0.10	0.61 ± 0.29
280	960	0.71 ± 0.26	<0.18	<0.56	<0.03	0.67 ± 0.42
280	1000	0.68 ± 0.20	<0.17	0.92 ± 1.89	0.10 ± 0.09	0.52 ± 0.32
280	1005	0.94 ± 0.18	<0.22	<0.72	<0.05	0.69 ± 0.23

a Errors are 2σ based on counting statistics.
b No sample collected; grid point inaccessible due to presence of surface water or landfill area.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES FROM LOCATIONS IDENTIFIED BY THE WALKOVER SCAN

Sample No.	Description	Grid Location		Radionuclide Concentrations (pCi/g)[a]				
		N	E	Ra-226	U-235[b]	U-238[b]	Cs-137[b]	Th-232[b]
B1A	Soil	539	222	2.60 ± 0.33[c]	<0.37	5.60 ± 1.30	0.13 ± 0.11	1.34 ± 0.36
B1B	Rock	539	222	5390 ± 99	<68.9	403 ± 369	<10.1	553 ± 84
B2A	Soil	538	222	2.25 ± 0.36	<0.27	1.47 ± 1.08	<0.04	1.28 ± 0.45
B2B	Rock	538	222	1830 ± 35	50.7 ± 53.3	211 ± 118	<3.44	152 ± 29
B3	Soil	536	224	1.04 ± 0.26	<0.21	3.05 ± 1.31	<0.03	0.69 ± 0.41
B4	Rock	521	758	1190 ± 39	<25.5	108 ± 121	3.00 ± 3.68	87.3 ± 28.2
B5	Soil	493	221	29.0 ± 1.3	<0.72	18.4 ± 3.2	0.55 ± 0.14	0.71 ± 0.79
B6	Soil	491	221	5.11 ± 0.45	<0.43	6.87 ± 1.65	0.29 ± 0.07	1.20 ± 0.55
B7	Rock	465	740	6660 ± 97	<61.7	<148	<8.72	98.5 ± 59.1
B8	Rock	460	742	11,200 ± 110	169 ± 175	<190	<11.2	<41.6
B9	Rock	458	364	2160 ± 36	<30.9	<76.8	<4.09	191 ± 35
B10	Chip	407	989	d	d	d	d	d
B11	Spark Gap	384	312	e	e	e	e	e
B12	Rock(Metallic)	376	292	4250 ± 61	<2.27	<45.8	<4.55	115 ± 39
B13	Rock	362	318	1660 ± 36	<34.8	<76.9	<3.59	43.3 ± 26.9
B14	Soil	360	299	0.95 ± 0.28	<0.20	1.78 ± 1.83	<0.04	0.89 ± 0.34

a Refer to Table 3 for direct radiation levels.

b Large relative errors and minimum detectable activities are the result of high continuum count rates caused by high Ra-226 levels.

c Errors are 2σ based on counting statistics.

d Small sample with Ra-226 activity too high for gamma spectrometry analysis; refer to Table 6 for total Ra-226 content.

e Small sample with Cs-137 activity too high for gamma spectrometry analysis; refer to Table 6 for total Cs-137 content.

TABLE 6

RA-226 AND CS-137 ACTIVITY IN SAMPLES FROM LOCATIONS OF ELEVATED DIRECT RADIATION LEVELS

Sample	Grid Location N	Grid Location E	Nature of Sample	Ra-226 (μCi)	Cs-137 (μCi)
B10	407	989	Plaster-like chip	0.31	---[a]
B11	384	312	Ceramic "spark-gap" device	---	25.4

[a] Dashes indicate negligible level.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.[a]	Grid Location N	Grid Location E	Depth (m)	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137	Th-232
H1	540	238	Surface	0.74 ± 0.20[b]	<0.18	<0.58	<0.02	0.84 ± 0.38
H2	528	758	Surface	0.63 ± 0.20	<0.16	0.98 ± 1.54	<0.03	0.67 ± 0.22
			0.5	0.65 ± 0.18	<0.17	0.94 ± 1.39	<0.03	0.93 ± 0.27
H3	522	1007	Surface	0.63 ± 0.23	<0.21	<0.67	<0.03	0.70 ± 0.37
			0.5	0.60 ± 0.26	<0.20	<0.71	<0.03	0.89 ± 0.30
			1	1.01 ± 0.26	<0.32	<0.99	<0.04	0.83 ± 0.32
			2	0.91 ± 0.21	<0.27	<0.85	<0.03	0.93 ± 0.41
H4	326	1002	Surface	0.86 ± 0.25	<0.27	2.04 ± 1.31	<0.04	1.03 ± 0.33
			0.5	0.78 ± 0.20	<0.22	0.80 ± 1.38	<0.04	1.03 ± 0.48
			2	1.05 ± 0.39	<0.32	<0.95	<0.03	0.96 ± 0.38
			3	0.93 ± 0.30	0.09 ± 0.06	2.48 ± 1.82	<0.05	0.75 ± 0.60
H5	320	645	Surface	1.14 ± 0.23	<0.27	1.20 ± 0.76	0.25 ± 0.09	1.03 ± 0.32
			0.5	1.19 ± 0.24	<0.21	1.11 ± 1.48	<0.03	1.02 ± 0.31
			1	0.98 ± 0.23	<0.30	2.22 ± 0.97	<0.04	1.13 ± 0.32
			2	0.85 ± 0.23	<0.19	1.82 ± 1.61	<0.03	1.44 ± 0.42
			3	0.98 ± 0.20	<0.25	2.21 ± 1.25	<0.04	0.74 ± 0.31
H6	325	184	Surface	0.88 ± 0.23	<0.19	1.22 ± 1.40	0.64 ± 0.11	0.88 ± 0.70
			0.9	0.85 ± 0.28	<0.27	0.97 ± 0.81	<0.03	0.91 ± 0.33
H7	370	290	Surface	1.11 ± 0.33	<0.25	1.56 ± 1.03	0.11 ± 0.06	1.16 ± 0.48
			0.5	0.71 ± 0.24	<0.18	<0.58	<0.03	0.78 ± 0.29
			1	0.94 ± 0.21	<0.25	<0.73	<0.03	0.93 ± 0.32
H8	365	300	Surface	1.79 ± 0.33	<0.21	<0.67	<0.05	0.96 ± 0.32
			0.5	0.95 ± 0.25	<0.21	<0.61	0.02 ± 0.03	0.72 ± 0.26
			1	1.08 ± 0.21	<0.32	2.12 ± 1.09	<0.04	1.40 ± 0.38
			2	0.89 ± 0.23	<0.19	1.05 ± 2.09	<0.03	1.43 ± 0.36
H9	365	310	Surface	0.99 ± 0.23	<0.28	1.44 ± 0.90	<0.04	1.01 ± 0.48
			1	1.04 ± 0.26	<0.27	2.68 ± 1.53	0.07 ± 0.06	1.21 ± 0.37
			3	1.31 ± 0.45	<0.25	<0.91	<0.05	0.98 ± 0.49
H10	360	320	Surface	1.01 ± 0.34	<0.18	<0.66	<0.05	1.08 ± 0.33
			0.15	0.86 ± 0.23	<0.28	1.91 ± 1.39	0.22 ± 0.14	0.73 ± 0.23
			0.3	1.04 ± 0.23	<0.27	3.32 ± 1.13	0.06 ± 0.04	1.02 ± 0.38
			1	0.75 ± 0.25	<0.17	<0.59	<0.04	0.48 ± 0.35
			6.1–6.7	1.16 ± 0.26	<0.31	3.96 ± 1.86	0.11 ± 0.07	1.24 ± 0.51

TABLE 7, cont.

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.	Grid Location		Depth (m)	Radionuclide Concentrations (pCi/g)				
	N	E		Ra-226	U-235	U-238	Cs-137	Th-232
H11	372	336	Surface	1.09 ± 0.31	<0.20	0.90 ± 1.40	<0.04	0.86 ± 0.51
			1	0.90 ± 0.21	<0.22	0.61 ± 1.57	<0.03	0.79 ± 0.29
			2	0.84 ± 0.25	<0.17	0.75 ± 1.20	<0.03	0.95 ± 0.40
H12	464	738	Surface	0.90 ± 0.25	<0.18	1.61 ± 1.59	<0.03	0.67 ± 0.34
			0.5	0.63 ± 0.21	<0.18	0.68 ± 1.34	<0.03	0.79 ± 0.31
			1	0.66 ± 0.19	<0.19	1.22 ± 1.33	<0.03	0.60 ± 0.35

a Refer to Figure 4.

b Errors are 2σ based on counting statistics.

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES

Sample No.	Sample Type	Grid Location		Radionuclide Concentrations (pCi/l)	
		N	E	Gross Alpha[c]	Gross Beta
W1	Surface Water[a]	400	680	<1.68	3.15 ± 3.98[d]
W2	" " [a]	320	560	<3.22	8.45 ± 7.14
W3	" " [a]	305	190	2.97 ± 4.43	6.53 ± 6.89
W4	" " [a]	305	960	5.05 ± 1.95	6.91 ± 2.93
W5	Subsurface Borehole H1[b]	540	238	1.02 ± 1.52	5.52 ± 2.25
W6	" " H3[b]	522	1007	6.19 ± 1.83	14.2 ± 2.7
W7	" " H12[b]	464	738	4.72 ± 1.90	22.9 ± 2.8
W8	" " H11[b]	372	336	3.76 ± 1.70	65.4 ± 3.3
W9	" " H10[b]	360	320	3.18 ± 2.06	5.55 ± 1.80

[a] Refer to Figure 5.
[b] Refer to Figure 4.
[c] Large amounts of dissolved solids resulted in relatively poor detection sensitivities and high errors for gross alpha analysis.
[d] Errors are 2σ based on counting statistics.

TABLE 9

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES
FROM DRAINAGE DITCHES

Sample No.[a]	Grid Location		Radionuclide Concentrations (pCi/g)				
	N	E	Ra-226	U-235	U-238	Cs-137	Th-232
SD1	320	560	1.18 ± 0.26[b]	<0.25	<0.92	0.10 ± 0.11	1.17 ± 0.46
SD2	305	190	0.76 ± 0.18	<0.29	1.82 ± 0.92	0.27 ± 0.08	1.10 ± 0.36
SD3	305	960	0.83 ± 0.20	<0.17	<0.68	0.32 ± 0.08	0.72 ± 0.45

[a] Refer to Figure 5.
[b] Errors are 2σ based on counting statistics.

TABLE 10

LISTING OF AREAS ON PROPERTY D WHICH EXCEED RESIDUAL CONTAMINATION CRITERIA LEVELS

Grid Location[a] N	E	Remarks
539	222	Each of these areas listed contains an isolated piece of rock-type material contaminated primarily with Ra-226. It is estimated that the total volume of these pieces of material is less than 2 m^3. Recent earthmoving activities on this property may have disturbed these areas, relocating or covering the source and possibly uncovering additional contaminated material not accessible during the survey described in this report.
538	222	
493	221	
491	221	
464	708	
384	320	
380	328	
380	330	
400	280[b]	
369	320	
363	326	
362	322	
361	310	
361	323	
361	325	
360	300	
360	308	
359	320	
358	320	
356	322	
356	328	
351	324	

a Refer to Figure 8.
b Relocated from 376N, 292E.

REFERENCES

1. E.A. Vierzba and A. Wallo, Background and Resurvey Recommendations for the Atomic Energy Commission Portion of the Lake Ontario Ordnance Works, Aerospace Corp., November 1982.

2. Oak Ridge Operations, U.S. Atomic Energy Commission, Radiation Survey and Decontamination Report of the Lake Ontario Ordnance Works Site, Oak Ridge, TN, January 1973.

3. T.E. Myrick, et al., Preliminary Results of the Ground-Level Gamma-Ray Scan Survey of the Former Lake Ontario Ordnance Works Site - Draft Report, ORNL, Oak Ridge, TN, 1981.

APPENDIX A

INSTRUMENTATION AND ANALYTICAL PROCEDURES

APPENDIX A

Instrumentation and Analytical Procedures

Gamma Scintillation Measurement

Walkover surface scans and measurements of gamma exposure rates were performed using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm x 3.8 cm NaI(Tl) scintillation crystals. Count rates were converted to exposure rates (μR/h) using factors determined by comparing the response of the scintillation detector with that of a Reuter Stokes model RSS-111 pressurized ionization chamber at locations on the Niagara Falls Storage Site and off-site properties.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal," Model PRS-1, portable scaler/ratemeters with Model HP-260 thin-window, pancake G-M, beta probes. Dose rates (μrad/h) were determined by comparison of the response of a Victoreen Model 440 ionization chamber survey meter to that of the G-M probes.

Borehole Logging

Borehole gamma radiation measurements were performed using a Victoreen Model 489-55 gamma scintillation probe, connected to a Ludlum Model 2200 portable scaler. The scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 cm x 7 mm holes evenly spaced around the region of the scintillation crystal. The probe was lowered into each hole using a tripod holder with a small winch. Measurements were performed at 15-30 cm intervals in all holes. The logging data was used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of Ra-226, U-235, U-238, Th-232, and Cs-137, there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

Soil and Sediment Sample Analysis

Gamma Spectrometry

Soil and sediment samples were dried, mixed, and a portion placed in a 0.5 l Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 600 to 800 g of soil. Net soil weights were determined and the samples counted using intrinsic germanium and Ge(Li) detectors (Princeton Gamma Tech) coupled to a Nuclear Data model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Ra-226 - 0.609 MeV from Bi-214 (corrected for equilibrium conditions)
U-235 - 0.143 MeV
U-238 - 0.094 MeV from Th-234 (secular equilibrium assumed)
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)
Cs-137 - 0.662 MeV

Water Sample Analysis

Water samples were rough-filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by subsequent filtration through 0.45 μm membrane filters. The filtrate was acidified by addition of 10 ml of concentrated nitric acid. A known volume of each sample was evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB 5100 low-background proportional counter.

Calibration and Quality Assurance

With the exception of the exposure and dose rate conversion factors for portable survey gamma and beta-gamma meters, all survey and laboratory instruments were calibrated with NBS-traceable standards. The calibration procedures for these portable instruments are described above.

Quality control procedures on all instruments included daily background and check-source measurements to confirm equipment operation within acceptable statistical fluctuations. The ORAU laboratory participates in the EPA Quality Assurance Program.

APPENDIX B

SUMMARY OF RADIATION GUIDELINES APPLICABLE TO OFF-SITE PROPERTIES AT THE NIAGARA FALLS STORAGE SITE

U. S. DEPARTMENT OF ENERGY

INTERIM RESIDUAL CONTAMINATION AND WASTE CONTROL GUIDELINES
FOR
FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM (FUSRAP)
AND
REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM (SFMP) SITES

(Review Within DOE Continuing)

Presented here are the residual contamination cleanup and waste control guidelines of general applicability to the FUSRAP project and remote SFMP sites[1/]. A site-specific analysis will be prepared for each FUSRAP and remote SFMP site prior to determining residual contamination guidelines for a specific site. In addition, it is the policy of the DOE to decontaminate sites in a manner consistent with DOE's as-low-as-reasonably-achievable (ALARA) policy. ALARA will be considered in reducing levels of residual contamination below applicable dose limits. ALARA will be implemented using cost/benefit considerations, and applied on a site-specific basis.

The soil residual contamination guidelines were developed on the basis of limiting maximum individual radiation exposure to DOE limits specified in DOE Order 5480.1A exclusive of exposure from natural background radiation or medical procedures. The radium-226 and thorium-230 guidelines include an additional limitation for buildup of radon-222 decay products in buildings. The aggregate of the contribution from all major pathways, based on scenarios for permanent intrusion, e.g., establishing residences on the site, was assumed. In most circumstances, the probability is low that such an intrusion will occur. Also, conservative assumptions were used in deriving these guidelines to ensure that a particular dose limit would not be exceeded. Use of these guidelines is additionally conservative because the pathways considered in the derivation of the guidelines assume all water intake and most food intake is from the site. Also, the FUSRAP and remote SFMP sites often have limited agricultural capability and the contamination is generally not homogeneous. The combined effect of these factors is such that the probable radiation exposure to the average population on, or in the vicinity of, FUSRAP or remote SFMP sites decontaminated to these guidelines will not be appreciably different from that normally received from natural background radiation.

The residual contamination guidelines for surface contamination of structures were adapted from guidelines developed by the U. S. Nuclear Regulatory Commission (NRC) for decontamination of facilities and equipment prior to release for unrestricted use or termination of licenses for byproduct, source, or special nuclear material [2/]. The waste control guidelines are consistent with applicable DOE Orders and EPA's regulations for inactive uranium milling sites, 40 CFR Part 192.

[1/]A remote SFMP site is one that is excess to DOE programmatic needs and is

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located outside a major operating DOE R&D or production area. Remote sites are more likely to be released to the public or excessed to other government agencies after decontamination than are sites located with major R&D or production areas.

[2] U. S. Nuclear Regulatory Commission 1982 Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, DC.

A. RESIDUAL CONTAMINATION GUIDELINES FOR FORMERLY UTILIZED SITES AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

The following guidelines represent the maximum residual contamination limits for unrestricted use of land and structures contaminated with radionuclides related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. A site-specific analysis will be prepared for each site prior to determining residual contamination guidelines for a specific site. It is the policy of DOE to decontaminate sites to contamination levels at or below the limits and in a manner consistent with DOE's as-low-as-is-reasonably-achievable (ALARA) policy on a site-specific basis. Site-specific guidelines and ALARA policy will be determined by DOE on a site-specific basis and an ALARA report filed on completion of remedial action at a site. Existing state and federal standards will be applied for water protection. Residual contamination limits for other nuclides will be developed when required using the same methodology[1] as was used for those represented here.

1. Soil (Land) Guidelines (Maximum Limits for Unrestricted Use)

Radionuclide	Soil Criteria[2],[3],[4] (pCi/g above background)
U-Natural[5]	75
U-238[6]	150
U-234[6]	150
Th-230[7]	15
Ra-226	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over 15 cm thick soil layers more than 15 cm below the surface and less than 1.5m below the surface.
U-235[6]	140
Pa-231	40
Ac-227	190
Th-232	15
Am-241	60
Pu-241[8]	2400
Pu-238, 239, 240	300
Cs-137	80

Sr-90	300
H-3 (pCi/ml soil moisture)	5,200

1/ Described in ORO-831 and ORO-832.

2/ In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its guideline shall be determined, and the sum of these fractions shall not exceed 1. There are two special cases for which this rule must be modified:

(a) If Ra-226 is present, then the fraction for Ra-226 should not be included in the sum if the Ra-226 concentration is less than or equal to the Th-230 concentration. If the Ra-226 concentration exceeds the Th-230 concentration, then the sum shall be evaluated by replacing the Ra-226 concentration by the difference between the Ra-226 and Th-230 concentrations.

(b) If Ac-227 is present, then the same rule given in (a) for Ra-226 relative to Th-230 applies for Ac-227 relative to Pa-231.

3/ Except for Ra-226, these guidelines represent unrestricted-use residual concentrations above background averaged across any 15 cm thick layer to any depth and over any contiguous 100 m^2 surface area. The same conditions prevail for Ra-226 except for soil layers beneath 1.5 m; beneath 1.5 m, the allowable Ra-226 concentration may be affected by site-specific conditions and must be evaluated accordingly.

4/ Localized concentrations in excess of these guidelines are allowable provided that the average over 100 m^2 is not exceeded. However, DOE ALARA policy will be considered on a site-specific basis when dealing with elevated localized concentrations.

5/ A curie of natural uranium means the sum of 3.7×10^{10} disintegrations per second (dis/s) over any 15cm thick layers from U-238 plus 3.7×10^{10} dis/s from U-234 plus 1.7×10^{9} dis/s from U-235. One curie of natural uranium is equivalent to 3,000 kilograms or 6,600 pounds of natural uranium.

6/ Assumes no other uranium isotopes are present.

7/ The Th-230 guideline is 15 pCi/g to account for ingrowth of Ra-226 as Th-230 decays. Ra-226 is a limiting radionuclide because its decay product is Rn-222 gas.

8/ The Pu-241 guideline was derived from the Am-241 concentration.

2. Structure Guidelines (Maximum Limits for Unrestricted Use)

a. Indoor Radon Decay Products

A structure located on private property and intended for unrestricted use shall be subject to remedial action as necessary to ensure the annual average concentration of radon decay products is less than 0.03 WL within the structure.

b. Indoor Gamma Radiation

The indoor gamma radiation after decontamination shall not exceed 20 microroentgen per hour (20 R/h) above background in any occupied or habitable building.

c. Indoor/Outdoor Structure Surface Contamination

Radionuclides 2/	Allowable Surface Residual Contamination 1/ (dpm/100 cm^2) Average 3/,4/	Maximum 4/,5/	Removable 4/,6/
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
U-Natural, Th-232, Sr-90, Fr-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000	15,000	1,000

1/ As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

2/ Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides shall apply independently.

3/ Measurements of average contaminant should not be averaged over more than 1 m^2. For objects of less surface area, the average shall be derived for each such object.

4/ The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 mg/cm^2 of total absorber.

5/ The maximum contamination level applies to an area of not more than 100 cm^2.

6/ The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels shall be reduced proportionately and the entire surface shall be wiped.

B. CONTROL OF RADIOACTIVE WASTES AND RESIDUES FROM FUSRAP AND REMOTE SFMP SITES

Specified here are the control requirements for radioactive wastes and residues related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. It is the policy of DOE to store radioactive wastes in a manner representing sound engineering practices consistent with DOE's ALARA policy.

1. Interim Storage

All operational and control requirements specified in the following DOE Orders and other items shall apply:

a. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations.

b. 5480.2, Hazardous and Radioactive Mixed Waste Management.

c. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities.

d. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements.

e. 5484.2, Unusual Occurrence Reporting System.

f. 5820, Radioactive Waste Management.

g. Control and stabilization features will be designed to ensure, to the extent reasonably achievable, an effective life of 50 years, and in any case, at least 25 years.

h. Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not (1) exceed 100 pCi/l at any given point, or an average concentration of 30 pCi/l for the facility site, or (2) exceed an average Rn-222 concentration at or above any location outside the facility site of 3.0 pCi/l (above background).

i. For water protection, use existing state and federal standards; apply site-specific measures where needed.

2. Long-Term Management

a. All operational requirements specified for Interim Storage Facilities (B.1) will apply.

b. Control and stabilization features will be designed to ensure to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years. Other disposal site design features shall conform with 40 CFR Part 192 performance guidelines/requirements.

c. Rn-222 emanation to the atmosphere from facility surfaces or opening shall not (1) exceed an average release rate of 20 $pCi/m^2/s$, or (2) increase the annual average Rn-222 concentration at or above any location outside the facility site by more than 0.5 pCi/1.

d. For water protection, use existing state and federal standards; apply site-specific measures where needed.

e. Prior to placement of any potentially biodegradable contaminated wastes in a Long-Term Management Facility, such wastes will be properly conditioned to (1) ensure that the generation and escape of biogenic gases will not cause the requirement in paragraph 2.c. to be exceeded, and (2) ensure that biodegradation within the facility will not result in premature structural failure not in accordance with the requirements in paragraph 2.b.. If biodegradable wastes are conditioned by incineration, incineration operations will be carried out in compliance with all applicable federal, state, and local air emission standards and requirements, including any standards for radionuclides established pursuant to 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants (NESHAPS).

C. EXCEPTIONS

Exceptions may be made to the guidelines presented herein following analysis of the site-specific aspects of a candidate site. Specific situations that warrant consideration for modifying these guidelines are:

1. Where remedial actions would pose a clear and present risk of injury to workers or members of the public, notwithstanding reasonable measures to avoid or reduce risk.

2. Where remedial actions would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future, notwithstanding reasonable measures to limit damage to the environment. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

3. Where the cost of remedial actions for contaminated soil is unreasonably high relative to long-term benefits and the residual radioactive materials do not pose a clear present or future hazard. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this hazard. Remedial actions will generally not be necessary where residual radioactive materials have been placed semipermanently in a location where site-specific factors limit their hazard and from which they are costly or difficult to remove, or where only minor quantities of residual radioactive materials are involved. Examples are residual radioactive materials under hard surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. Supplemental standards shall not be applied at such sites, however, if individuals are likely to be exposed for long periods of time to radiation from such materials at levels above those that would prevail in Subpart A.

4. Where the cost of cleanup of a contaminated building is clearly unreasonably high relative to the benefits. Factors that shall be included in this judgment are the anticipated period of occupancy, the incremental radiation level that would be affected by remedial actions, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of less costly remedial methods than removal of residual radioactive materials.

5. Where there is no known remedial action.

D. GUIDELINE SOURCE

Guideline	Source
Residual Contamination Criteria[1/]	
Soil Guideline	DOE Order 5480.1A, 40 CFR Part 192[2/]
Structure Guideline	40 CFR Part 192, NRC Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material (July 1982).
Control of Radioactive Wastes and Residues	
Interim Storage	DOE Order 5480.1A
Long-Term Management	40 CFR Part 192

[1/] The bases of the residual contamination guidelines are developed in ORO-831 and ORO-832.

[2/] Based on limiting the concentration of Ra-222 decay products to 0.03 WL within structures.